(2)

ANNOTATED BIBLIOGRAPHY ON RELATIVE MOTION

MARCH 1992

FINAL

Prepared for: ANNAPOLIS DETACHMENT, CARDEROCK DIVISION NAVAL SURFACE WARFARE CENTER

Prepared by: COLUMBIA RESEARCH CORPORATION

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution unlimited.
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S)	5. MONITORING ORGANIZATION REPORT NUMBER(S) DTRC-SD-CR-08/92
6a. NAME OF PERFORMING ORGANIZATION Columbia Research Corporation 6b. OFFICE SYMBOL (If applicable)	7a. NAME OF MONITORING ORGANIZATION Carderock Division, Naval Surface Warfare Center
6c. ADDRESS (City, State, and ZIP Code) Arlington, VA 22202	7b. ADDRESS (City, State, and ZIP Code) Bethesda, MD 20084-5000
8a. NAME OF FUNDING/SPONSORING ORGANIZATION Naval Civil Engineering Lab. 8b. OFFICE SYMBOL (If applicable) L65	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER N61533-91-D-0027/0004
8c. ADDRESS (City, State, and ZIP Code) Port Hueneme, CA 93043-5003	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO. 62233N; PROJECT NO.; TASK NO.; WORK UNIT ACCESSION NO.

11 TITLE (Include Security Classification)
(U) ANNOTATED BIBLIOGRAPHY ON RELATIVE MOTION

12 PERSONAL AUTHOR(S)
Matsko, John S. and Leeson, David H.

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Final	FROM 91/03/13 TO 92/03/13	1992 March	90

16 SUPPLEMENTARY NOTATION
Focus is relative motion as it affects cargo transfer at sea.

17 COSATI CODES		
FIELD	GROUP	SUB-GROUP

18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
Relative Motion; Logistics Over The Shore (LOTS); Cargo Handling; Motion Compensation; Logistics; Offshore Oil Industry

19 ABSTRACT (Continue on reverse if necessary and identify by block number)
To transfer cargo successfully between ships at sea, or between ships and platforms offshore, requires the capability of managing relative motion. Relative motion is motion of one body relative to another. The relative motion is what must be overcome to effectively move cargo from one vessel, or platform to another in an open seaway. The problem ranges from insignificant in a protected harbor to virtually impossible in a gale at sea. Concepts for military logistic bases offshore require solutions be developed to the relative motion problem for cargo transfer in many different sea and wind conditions.

This annotated bibliography is an attempt to identify in one place much of the work that has been done to date by the military and commercial industry to overcome the problems causes by relative motion. This bibliography documents solutions developed by the Navy and the offshore oil industry, and some patented concepts not fully developed.

(Continued on Reverse)

20 DISTRIBUTION/AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED
22a NAME OF RESPONSIBLE INDIVIDUAL Keith R. McAllister	22b TELEPHONE (Include Area Code) (410) 267-2261 22c. OFFICE SYMBOL Code 1235

DD FORM 1473, 84 MAR 83 APR edition may be used until exhausted
All other editions are obsolete

SECURITY CLASSIFICATION OF THIS PAGE
UNCLASSIFIED

This bibliography is organized into two sections:

1. Alphabetical list of tiles referencing the citation sequence number.
2. Citation list in numerical sequence organized alphabetically by author's name, followed by an abstract where available.

ANNOTATED BIBLIOGRAPHY
ON
RELATIVE MOTION

To transfer cargo successfully between ships at sea, or between ships and platforms offshore, requires the capability of managing relative motion. Relative motion is motion of one body relative to another. The relative motion is what must be overcome to effectively move cargo from one vessel, or platform, to another in an open seaway. The problem ranges from insignificant in a protected harbor to virtually impossible in a gale at sea. Concepts for military logistics bases offshore require solutions be developed to the relative motion problem for cargo transfer in many different sea and wind conditions.

This annotated bibliography is an attempt to identify in one place much of the work that has been done to date by the military and commercial industry to overcome the problems caused by relative motion. This bibliography documents solutions developed by the Navy and the offshore oil industry, and some patented concepts not fully developed. For example, the Navy transfers cargo ship-to-ship today using underway replenishment systems. Additionally, the Navy transfers cargo from ship-to-shore in support of amphibious assault using small craft or lighters. The offshore oil industry has developed numerous heave compensation systems to alleviate the effects of vessel heave on drilling operations. The primary focus of the 321 citations listed herein are the mitigation of relative motion for cargo transfer operations

This bibliography is organized into two sections:

1. Alphabetical list of titles referencing the citation sequence number.
2. Citation list in numerical sequence organized alphabetically by author's name, followed by an abstract where available.

A citation may be located by either title or principal author's name.

1. Aalbers, A. B. and V. Nienhuis, *"Wave Direction Feed-Forward on Basis of Relative Motion Measurements To Improve Dynamic Positioning Performance,"* in: Offshore Technology Conference Proceedings, OTC Paper 5445 (1987).

A method is described which may improve the dynamic positioning of large ships in wind and waves, especially in case of non-parallel wind and wave directions. The proposed method applies the measurement of relative motions at two opposite side locations to estimate the wave direction and the wave drift force level. Combination with the wind measurements leads to an optimum heading set-point. The potential improvements are illustrated by results of tests and dynamic positioning simulations.

2. Abkowitz, Martin A., *"Relative Motion Between LCU and Mariner Models in a Seaway,"* Massachusetts Institute of Technology (Oct 1976).

A program of model seakeeping tests was carried out in the M.I.T. ship model towing tank for the purpose of estimating the relative motion between the deck of an LCU and the top end of a cargo boom on a mariner ship during a typical offshore unloading situation. A five foot long mariner model, scale 1 to 96 (1/8 inch = 1 foot), was available at the tank and the LCU model was built to this scale. Tests were carried out in scaled sea states 3 and 4 which were simulated by irregular seas of the Pierson-Moskowitz spectra representing fully developed seas of wind speeds of 15 knots and 18 knots respectively.

3. Abkowitz, M.A., *"Relative Motion Between LCU and Mariner Models in a Seaway (Addendum),"* M.I.T. Report (Mar 1977).

4. Alexander, G.H., *"Apparatus and Method for Wave Motion Compensation and Hoist Control for Marine Winches,"*
US PATENT-4 547 857 (Oct 1985).

A wave motion compensator for a marine winch, in which the tension on the winch rope is maintained substantially constant while the load on the rope moves relative to the winch. This constant tension is maintained by controlling the winch drive motor so that the movement of the winch rope matches the movement of the load without substantial lag. The control is provided by a computer which repeatedly monitors the movement of the winch rope and, by comparing this input data and standard sea state data, predicts the relative movement of the load and the winch at a time in advance of the time the prediction is made at least as long as the lag time of the winch system. The computer then issues appropriate commands to the winch drive motor controller. In marine applications involving the lifting or lowering of loads, the computer is also used to determine the optimum time for initiating lifting and completing lowering of the load, and to automatically perform these operations.

5. Alzinger, E. and V. Brozovic, *"Automation and Control System for Grab Cranes,"* Brown Boveri Review, Vol. 70, No. 9-10, pp. 351-6 (Sep - Oct 1983).

The automation and control system with the programmable controller PROCONTIC DP800 and a terminal with colour CRT display, by providing full automation, enables maximum use to be made of grab cranes for unloading ships. Its main functions are guideline and grab control and compensation of the grab swings by controlling the acceleration and retardation of the trolley. The authors take a close look at this method, which is known as discontinuous swing compensation.

6. American Petroleum Institute, *"Offshore Cranes, API Specification 2C,"* 2nd Edition (Feb 1972).

7. Anderson, Adolph, *"Automatic Coupling For Hoisting Heavy Loads,"* US PATENT-3 428 356 (Feb 1969).

This invention relates to coupling devices, and more particularly to a self-acting coupling, or hook, adapted to be used with a hoist or the like, and which automatically couples the hoist to the load upon performance of a first and second movement of the hook under control of the hoist operator without the need for stationing even one man at the hook or load to perform a direct coupling action. Uncoupling is performed by another pair of movements of the hook under control of the hoist operator.

It is a primary object of the invention to provide a coupling hook, for lifting heavy loads, which is self-acting to couple and uncouple without the need for manual assistance, the coupling and uncoupling taking place automatically by relative movements of the coupling and the load under control of the hoist operator in lifting and lowering the hooks.

8. Anon., *"Cargo Handling and Deck Machinery,"* Marine Engineering Log, Vol. 92, No. 2, pp. 35-42 (Feb 1987).

Drastic changes have taken place in the world's shipping industry in recent years - and will continue into the foreseeable future. Cargo handling and its related equipment both aboard ship and ashore must rank as one of the most revolutionary developments in the industry. While newer, improved designs in cranes, winches and similar equipment have appeared, computerization in operation of loading and unloading devices is the development that has opened up new territories for improvement in efficiency, speed and economy. Ship stability problems in the loading and unloading modes are now computer controlled, as is container handling equipment aboard and ashore - such as cranes and spreaders.

9. Anon., *"Fishing Pole Concept Seen as Lifesaver,"* Offshore, Vol. 45, pp. 176 (May 1985).

A contingent of Canadian companies and associations are completing field tests of a unique rescue system designed to eliminate the potential disasters inherent in normal lifeboat launchings during bad weather. The relatively simple concept includes an 80-ft flexible fiberglass boom held by a saddle support and hinge that are mounted on the rig at the evacuation stations. In its normal position, the boom rests at an elevated 45° angle. At the tip of the boom a wire cable or tagline, which is the same length as the boom, is connected to the bow of the lifeboat. As the lifeboat is lowered vertically towards the water by its regular launch cables, horizontal tension is transferred to the lifeboat by the tagline and boom causing the vessel to lower diagonally down and away from the rig.

10. Anon., *"New Crane Boasts Many Advantages,"* Marine Engineering Log, Vol. 78, No. 11 Oct, pp. 45, 114 (1973).

The newly developed and patented design, which the Cushing firm terms the ECONCRANE, was specifically adapted to Delta's LASH vessels, and boasts many important advantages over conventional shipmounted cranes. A significant weight reduction and a lower center of gravity have been realized by the elimination of jibs for outreach, and by the use of a single, transverse box girder supported by only two legs and truck-mounted sills. The crane also can handle any

size container or oversized load, and could easily be married to another similar type of crane to handle large, heavy, or awkward loads. All components and systems have been designed with simplicity of operation, high component reliability, and ease of service and maintenance as design parameters of prime importance.

11. Anon., *"Saga To Have Active LSIS Heave-Compensating System,"* Ocean Industry, pp. 59 (Apr - May 1990).

The Light Subsea Intervention System (LSIS) is an active heave-compensated load handling system that has been selected to deploy the remotely operated maintenance vehicle (ROMV) being built for work at Saga Petroleum's Snorre field. A crucial point of LSIS is its ability to respond very quickly to vessel heave. The main LSIS components are an electronically controlled hydraulic system, several load cells and pressure gauges and a mathematical process model. Heave-motion data are generated by accelerometers aboard the vessel, allowing loads to be handled without a fixed external reference point.

The system is designed to operate from a moderate sized monohull vessel instead of a semi-submersible or a large monohull. Testing of the prototype took place on a 216-ft supply and anchor handling vessel. Wave movements of up to 6 m (20 ft) provided an environment for realistic trials. Residual load movements were mostly within the +/- 15 cm and never exceeded +/- 30 cm. Landing velocity of the load was 30 cm/sec.

12. Applebaum, Sidney P., *"Platform Motion Compensating,"* Dept. of the Navy, US PATENT-3 806 924 (Apr 1974).

13. Arai, Shin-ichi, *"Effective Method for Reducing the Motion of Moored Floating Vessels,"* Hitachi Zosen Technical Review, Vol. 43, No. 4, pp. 220-227 (Dec 1982).

To reduce the slow drift oscillation of moored vessels due to winds and waves, a method was considered in which a sliding block on a sea-bed is connected by a spring with the moored vessel. It was anticipated that the Coulomb friction between the block and the sea-bed reduce the vessel motion. Experimental tests of an idealized model excited by sinusoidal forces were carried out. In addition, numerical simulations using the Runge-Kutta-Gill method, availability of which had been confirmed for the experiments, were carried out on an actual model excited by irregular wind forces. The following conclusions were obtained. (1) This method is highly effective in reducing vessel motion. (2) The reducing effect is influenced not by the mass of the block, but by the friction and the connecting spring. (3) There is an optimum ratio of friction force to exciting force to minimize the vessel motion.

14. Arctec Offshore Corporation, *"A Study of Mobile Offshore Drilling Units Converted for Use As Temporary Unloading Facilities For Military Cargo,"* Arctec Offshore Corporation Report MA-RD 840-88003 (Sep 1988).

The Navy Strategic Sealift Program provides the ships and cargo handling systems to load, transport and offload equipment and material of U.S. military forces anywhere in the world. There exists a strong national requirement for military sealift capacity that will use existing commercial vessels in times of contingency or war. Unfortunately, recent trends in the maritime industry have developed vessels which are large and economical but which are highly dependent on shore support facilities for loading and unloading and thus less suited for military support use. Because of this, there is particular interest in developing innovative schemes for discharging and loading non-selfsustaining vessels in areas where access to shore-based handling gear may not be

available. Fortunately, the U.S. has available a large number of vessels in its offshore exploration fleet which are fully capable of handling cargo at sea. Many of these vessels (mobile offshore drilling units - MODUs) are currently available due to the downturn in the offshore drilling industry and are likely to remain available for some time into the future (Figure 3.1). The purpose of this project was to examine ways of utilizing both jack-up and semi-submersible MODUs as Flexible Initial Response Shipping Terminals (F.I.R.S.T.).

15. Azpiazu, W. and P.R. Doster, "*Practical Procedures for Heave-Compensator Operation in Deep Water and Bad Weather,*" Oil and Gas J., Vol. 84, No. 19, pp. 60-64 (May 12, 1986).

A review of operating procedures for drillstring compensators was undertaken and recommendations were made in an attempt to help the driller and the project engineer who operate equipment in deep water and during bad weather in offshore exploration. This information is based on present practices and literature that describes current operational methods for landing and tensioning the large loads and pipes characteristic of the offshore industry. Research was applied to extend these procedures and new techniques proposed for handling hangers, trees and risers in the more hostile and rigorous environments encountered today. The purpose is to increase safety and the operational weather window for offshore vessels. (from paper)

16. Azpiazu, Wenceslao, M. T. Thatcher, and E. R. Schwelm, "*Heave Compensation System: Analysis and Results of Field Testing,*" Annual Offshore Technology Conference 15th, OTC Paper 834,561, Vol. 2, pp. 417-424 (May 2-5, 1983).

A program to determine the performance of heave compensator systems under actual at-sea working conditions has been undertaken. As a result of this test program, parameters have been determined for heave compensation systems that will allow design of these systems with pre-established performance goals. A description of the methods used to determine the coefficients that control system performance is presented and equations are given to determine system response to the full spectrum of envisioned working conditions. 7 Refs.

17. Azpiazu, Wenceslao and Peter R. Doster, "*Heave Compensator Operation in Deep and Bad Weather,*" Deep Offshore Technology 1985: 3rd International Conference and Exhibition Proceedings (Oct 21-23, 1985).

An attempt is made to review and recommend operating procedures for drill string compensators, to help the driller and the project engineer who have to face deep water and bad weather during their duties. This paper is based on present practice and literature review to describe current operational methods for the landing and tensioning of the large loads and pipes characteristic of the offshore industry. Research is applied to extend these procedures and propose new techniques applicable to the handling of hangars, trees and risers in the harsher environments subject of the Deep Offshore Technology Conference, in order to increase the operational weather window of offshore vessels. 15 Refs.

18. Babbi, H., "*Ship Transport System,*" VMW Industries, US PATENT-4 666 357 (May 19, 1987)

Abstract: A transport system for transporting a litter carrier from one location onboard a first ship to a second location onboard another ship includes a retractable boom having a stationary member and a telescoping member slidably engaged therein. Boom also includes a hoist unit which is operatively connected through a hoist cable to carrier to cause movement thereof. Carrier includes acoustic rangefinders and contact detectors which are electrically coupled to a control circuit located onboard one of the vessels through internal electrical conductors in hoist cable.

Rangefinders generate signals indicative of the distance between carrier and a selected one of the ships. Contact detectors provide signals which indicate whether carrier is in transit or has landed onto a ship. Control circuit is operable to receive signals from acoustic rangefinders and contact detectors to compensate the operation of hoist and carrier for the relative motion between the two ships, thereby effecting a smooth transfer of the carrier between the ships.

19. Baitis, A.E., *"Final Summary of General Dynamics Seaworthiness Tests of LHA Landing Craft Loading Problems,"* DTNSRDC T & E Rept HML-P-231-H-10 (Oct 1969).

This report presents the results of a seaworthiness test program conducted at the Naval Ship Research and Development Center to study problems associated with the loading and unloading of amphibious assault craft from the Helicopter Assault Ship (LHA). Contained, are the body plans of the LHA and the four landing craft tested, namely the LCU, LCM8, LCM6, and LCAX2. Plans for the tested LCU represent a version of the FY 67 LCU. This version was similar to but not identical to the 1610 class of LCU. The tested model was representative of the 1610 class. Full scale particulars of the landing craft and the General Dynamic's LHA are presented. The sea states used during these experiments are defined and a sample wave height spectrum used throughout the test program to represent sea state 3 is presented. A model to prototype scale ratio of 23.4:1 was used during the tests.

20. Baker, R. J., *"Improved Heave Compensation,"* Proc. Drill Conf. Publ by Soc of Petroleum Engineers of AIME, PP. 565-70 (1991).

The efficiency of drilling operations carried out from floating drilling units in hostile environments is adversely affected by movement of the vessel, particularly heave. Over the years, various systems have been developed in an endeavor to minimize the problems caused. This paper describes the impact that heave has on the efficiency of floating drilling operations, the compensatory methods and systems that have been used to date, and highlights some new developments that promise to improve safety and drilling performance, while reducing the potential adverse environmental effects of drilling operations. (Author abstract) 5 Refs.

21. Balfour, A.D. and D.G. Owen, *"Dynamic Behavior of Platform Cranes,"* in: Offshore Technology Conference Proceedings, OTC Paper 803,794 (1980).

Mathematical models of varying complexity are developed to predict forces occurring in a typical offshore platform crane while lifting from a supply boat. Computer programs based upon these models are used to assess the usefulness of these simulations. It is shown that a simple two degrees of freedom model can be usefully employed at the feasibility design stage whereas a more sophisticated multi-degree of freedom model is required for detailed crane design. These programs are used to investigate the influence upon the induced loads of various operational parameters including the load lifted, the jib angle, the line speed and the instantaneous deck velocity. It is concluded that high dynamic loads will frequently arise in such cranes and that specifically written computer programs are necessary for effective derating or design. A statistical approach to the assessment of supply boat motions is used to show that maximum deck velocities can greatly exceed those predicted by the simpler methods previously used.

22. Barbara, Norman R., *"Control Means For Motion Compensation Devices,"* US PATENT-4 349 179 (Sep 1982).

A control system for stabilizing a body suspended by a flexible line from a structure such as a

ship, which is subject to uncontrolled oscillating movements, such as may be caused by wave motion, incorporates a winch to which the line is attached, a pulley over which the line passes and from which the body is suspended, and a loop in the line between the winch and pulley, an accelerometer being located adjacent the pulley, and the length of the loop being altered in controlled response to a stabilizing signal formed by combining signals derived from the accelerometer, and from the measured amplitude of oscillations of the loop length, and modified by a compensating signal to compensate for the effect of friction in the system.

23. Barron, Charles D., "*Displacement Control System For Hoist Apparatus*," US PATENT-3 753 552 (Aug 1973).

A displacement control system for hoist apparatus, in which the winch is driven by a drive which is controlled by a pneumatic signal derived from a pressure controller, the controller output pressure signal being determined by comparing in a computing pneumatic relay variable signals derived from a relative motion responsive reference sensor, a load position sensor, and a speed sensor.

24. Barron, Charles D., Earl A. Peterson, Gary K. Stark, and Carl A Wilms, "*Marine Platform Structure*," US PATENT-3 804 268 (Apr 1974).

A motion compensating hoist for moving a load between relatively vertically movable points, in which a cable from a tensioning hoist is interconnected between the two points, and the cable from a load hoist is connected to the load, and the tensioning hoist and the load hoist are cooperable to establish movement of the load corresponding to the relative movement between the two points and to cause further movement of the load between the two points.

25. Barron, Charles D., Earl A. Peterson, Gary K. Stark, and Carl A. Wilms, "*Motion Compensating Hoist*," US PATENT-3 675 900 (Jul 1972).

A motion compensating hoist for moving a load between relatively vertically movable points, in which a cable from a tensioning hoist is interconnected between the two points, and the cable from a load hoist is connected to the load, and the tensioning hoist and the load hoist are cooperable to establish movement of the load corresponding to the relative movement between the two points and to cause further movement of the load between the two points.

26. Barron, Charles D., Earl A. Peterson, Gary K. Stark, and Carl A. Wilms, "*Stabilized Load Hoist Apparatus*," US PATENT-3 648 858 (Mar 1972)

Hoist apparatus for moving a load between relatively vertically movable locations, wherein the load is moved by a pair of load hoist cables, and a tension hoist cable is connected between the relatively vertically movable locations, the load hoist and the tension hoist being coupled together to cause movement of the load corresponding to the movement between the locations, the load hoist also being operable to move the load between such locations, the load being connected to the pair of load hoist cables and being guided on the tension hoist cable.

27. Bascomb, M.M., "*Environmental Analysis Relative to Portable Port Operations*," Ocean Science and Engineering, Inc. (Nov 1969).

A study of the oceanographic environment at eleven remote semi-tropic coastal areas and the

effects of these environments on the deployment and operation of the Portable Port systems defined in Proposed Technical Approaches - 41 Element No. 63712N, Project No. Y41BC prepared by the Naval Facilities Engineering Command, February 01, 1969.

28. Battelle Columbus Laboratories, *"Deep Ocean Recovery System Vehicle Launch Crane, Summary Report,"* (Aug 1978).

29. B. C. Research, *"Analysis of the Dynamics of a Motion Compensating Crane,"* B.C. Research Report (Jul 1976).

This report documents the analysis of a shipboard motion compensating crane for transferring loads from one ship to another in a given sea state. The mother ship, on which the crane is located, is the C4-S-1A Tarheel Mariner, and lighter is the LCM-8. The geometric configuration of the two ships is shown. The crane under consideration is a standard P&H 9125, with fixed boom geometry. The object of this analysis is to specify a control scheme for synchronizing the load motion to the lighter deck motion, such that impact velocities are less than 2 ft/sec for the given sea state; and the specify a configuration of anti-sway tag lines such that the side load due to pendulation of the load is less than 2 percent of the related crane load.

30. Bechtel Corporation, *"Study of Mobile Emergency Port Facilities,"* Bechtel Corporation Report PB 184348 (Jun 1969).

The subject of this study is the conceptual design of a mobile emergency port package capable of restoring a disaster-stricken port to partial operation or creating a temporary port in an unimproved area. An analysis was made of a number of port disasters in the period since World War II in order to gain insight as to the need and possible effectiveness of a mobile emergency port package. The sampling included natural disasters, such as earthquakes and hurricanes; accidental disasters, such as fires and explosions; military operations involving landings; and ports damaged by military action.

31. Begault, Rudolph A., *"System And Apparatus For Transfer Of Personnel/Cargo Between A Marine Platform And Crew Boat,"* US PATENT-3 794 187 (Feb 1974).

The present disclosure is directed to a system and apparatus for employing the compressibility of a gas (air) to provide a variable length, load carrying, member in a suspension system used for transporting a load (personnel, cargo, provision, etc.) from one point to another, between which points there is relative motion. This device incorporates the foregoing basic idea into a system which eliminates relative oscillatory motion between a load and an oscillating point to which the load is being transferred, while allowing relative linear motion between the load and the oscillating point.

32. Belinsky, S.I., *"Swap Type Floating Platforms,"* US PATENT-4 864 958 (Sep 1989).

Abstract: A system for stabilizing floating semi-submersible platforms and compensating ship motion of monohull ships is based on a design protecting waterplane from vertical movement during wave actions. Each vertical strut of the semi-submersible platform utilizing this system consists of a vertical hollow column with its upper end connected to the platform upper structure and lower end open to the surrounding water. Inside the vertical hollow column is inserted a buoyancy vessel which is connected to the upper platform structure by its upper part and which

serves as a means of forming a waterplane. During passive mode of this system operation, the roll and pitch of the floating platform (ship), due to wave induced forces, will be introduced because the vertical movement of the water level inside the vertical hollow column will be considerably less than the vertical moment of the water outside the vertical hollow column. During the active mode of the SWAP system operation, the roll and pitch of the floating platform (ship), due to wave induced forces, or trim and list, due to the outer moment acting on the ship, will be eliminated or drastically reduced by changing the air pressure in the space between vertical hollow columns, inserted buoyancy vessel and waterline inside the vertical hollow column.

33. Belsterling, C. A., G. C. Gambs, and H. B. Hammill, "*Design Studies for a Stabilized Shipboard Crane,*" Franklin Research Center, Final Report, Contract Number DTMA91-86-C-60127, Report Number F-6171-001 (Oct 1986 - Sep 1987).

The Logistics-Over-The-Shore (LOTS) mission requires the capability to off-load containers and break-bulk cargo from large oceangoing ships onto a variety of lighters (and other small craft). Off-loading must be accomplished in all types of weather and in the presence of high sea states. Problems arise due to the motions of the vessels in inertial space and the motions of the vessels relative to each other. Existing shipboard cranes use a single cable with a cargo coupling mechanism (spreader) suspended from an overhead structure. Ship motion forces the cargo (or spreader) into pendulous action, allowing it to swing unchecked. Extreme difficulty is encountered when trying to mate the spreader with a container that is on the oceangoing vessel itself. Furthermore, depositing the swinging container on to a moving lighter without damage to cargo and hazards to personnel is even more difficult.

The Franklin Research Center has devised a means to stabilize suspended cargo in all six degrees of freedom (DOF), using six individually controlled cables in tension in a unique kinematic arrangement. These design studies establish the technical and economic feasibility of the new, stabilized cargo-handling system.

34. Belsterling, C. A., "*Stabilized Shipboard Crane,*" US PATENT- 4 932 541 (Jun 12, 1990).

Abstract: The invention is directed to a stabilized cargo-handling system using means for stabilizing suspended cargo in all six degrees of freedom using six individually controlled cable in tension in a unique kinematic arrangement. Inertial and distance sensors, coupled with high-performance cable drives, provide the means to control the multi-cabled crane automatically. The distance sensors are used to track the target container or lighter during the pickup and setdown modes of operation; The inertial sensors are used to prevent pendulation during transfer of the cargo from the seagoing cargo ship to the vicinity of the receiving lighter. The complete stabilized shipboard crane system permits safe and efficient operations in relatively high sea states.

35. Berger, Sydney, "*Preliminary Assessment of Lighter Damping Augmentation in Heave for Reduction of Relative Motion,*" Final Report, Control System Research Inc., CSR-339 (Jul 1972).

The concept of augmenting the inherent damping of a lighter hull to suppress its heave response in waves, and thereby to reduce relative motion between a cargo ship and lighter is the subject of this investigation. The scope of the effort was a minimum one to rapidly assess the promise of the concept. A primarily empirical approach was taken. Sufficient analysis was included to interpret the test results and to consider the implications of the results in full scale.

Model tests were performed in a model basin with wave making facility. The model consisted of a one-sixth scale hull for a 45 ft. long patrol boat with its damping appendage slats, one or two

high, longitudinally aligned on either side. Model mounting arrangements on the stationary carriage of the towing tank locked out all motions other than heave. Tests covered the model at two displacement conditions of bare hull, with single row damping, with double tow damping. Wave lengths were in the range of 6 to 16 ft. Wave heights were between 2.6 and 5.0 inches, with the attempt made to obtain the steepest possible wave without wave form distortion.

36. Bergman, G.B., *"Heave Stabilization of Semi-Submersible Platforms,"* Seatek Corporation, US PATENT-4 112 864 (Sep 1978).

Semi-submersible offshore drilling platforms are stabilized to reduce heave at wave periods which are shorter than those at which heave resonance occurs. Platform structures include supporting columns and pontoons. The pontoons extend outboard of the columns and have non-uniform cross sections. In addition, the pontoons may be shifted outwardly from the column center-lines. Reduced heave response to head-on, stern-on and beam waves is achieved.

37. Bergman, G.B., *"Method and Apparatus for Stabilizing a Floating Structure,"* Seatek Corporation, US PATENT-4 167 147 (Sep 1979).

A floating semi-submersible platform is heave stabilized by velocity damping of platform motion. Vertical velocity of the platform as a function of and in opposition to the sensed heave velocity. The system may be passive, as by provision of velocity damping in tethering cables. It may be actively hydrostatic by employing variable ballast tanks and water pumps of air pressure for displacement of water, or it may be actively hydrodynamic by employing propellers or rotor blades for thrust generation. By applying a heave opposing force that is proportional to heave velocity, the platform response to waves at the platform resonant period is greatly reduced with exertion of relatively small magnitude opposing forces, whereby the platform may be designed with a considerably smaller resonant period for a given set of expected conditions.

38. Bergman, G.B., *"Method and Apparatus for Suppressing Heave in a Floating Structure,"* Seatek Corporation, US PATENT-4 452 165 (Jun 1984).

A heave resonant damper for semi-submersible platforms includes tanks and ducts constructed so that their resonant period approximately equals the resonant heave period of the platform, wherein the ducts have selectively varied cross-sectional area to optimize damping.

39. Berkley, J.B. and N.F. Johnson, *"Engineering Report: San Diego Bay Tethered Float Breakwater,"* Ocean Technology Department, Naval Undersea Center (1976).

40. Beser, J., *"Highly Accurate Hydrographic Surveys Using Differential GPS,"* IEEE PLANS '86 Position Location and Navigation Symposium, pp. 169-76 (1986).

During the acquisition segment of a hydrographic survey, vessels equipped with sonar equipment measure the local depth as well as their own position. For an accurate survey to be performed, the vessel position must be known accurately, heave motion must be measured and compensated, and the vessel's attitude must be known. The Navstar Global Positioning System (GPS), operated in the differential mode, can provide an accuracy on the order of 5 m or better for ship positioning. GPS, augmented with other low-cost sensors, can also provide the required accuracies for heave and attitude compensation. A system concept to achieve these accuracies is described, with emphasis on ease of integration, cost minimization, selection of readily available,

off-the-shelf equipment, and crew work load reduction. Proposed implementations are presented for the different shore station, the shipboard system, and the data link system. Results of computer simulations for alternative shipboard filter designs are provided.

41. Bird, J. Dexter III, *"Development of a Full Scale Platform Motion Compensator,"* EG&G Washington Analytical Services Center, Inc. Report TR-W2709-012 (Apr 1985).

42. Bird, J. Dexter III, D.B. Dillon, L.A. Kahn, *"Analysis and Design of Impact Absorbers for Offshore Cranes,"* EG&G Washington Analytical Services Center, Inc. (Aug 1981).

43. Bird, J. Dexter III, *"A Methodology for the Evaluation of Alternative Offshore Container Discharge Systems,"* EG&G Washington Analytical Services Center Report TR-D200-0002 (1982).

A methodology has been developed for the evaluation of the cost and effectiveness of a complex system of dynamic elements driven by a single random input. This methodology was developed for the evaluation of amphibious material handling systems and applied to the Navy's Container Offloading and Transfer System (COTS). An example system configuration has been examined in detail in order to demonstrate the application of the methodology and the type of data needed to develop the necessary system relationships. A variety of applications were demonstrated, including determination of the effects of sea state and breakwaters and analysis of the tradeoff between breakwaters and motion compensating cranes. It was demonstrated that the methodology is easily adaptable to multidimensional optimization by the use of numerical techniques such as the steepest descent algorithm. This methodology relies heavily upon Gaussian inputs, linearizable dynamic properties of the system elements, and a minimum of coupling between the dynamic elements. Future research should examine the possibility of handling non- Gaussian inputs, system dynamics that the not readily linearized, and systems where strong coupling exists between the dynamic elements. In the particular case of the COTS problem, several areas warrant further investigations. More complex forms of motion compensating crane strategies should be examined, such as those that track the relative displacement between the cargo and the adjacent craft or optimal strategies that anticipate relative motion and land the cargo on the peaks where relative velocity is minimized. The interactions between the floating elements should be examined in greater detail. Particular attention should be given to the sheltering of one craft by another and the effects of secondary wave generation from the motions of the larger vessels. Finally, additional data needs to be collected in order to more accurately establish the component cost models and to verify or develop improved expressions for the container offload cycle times.

44. Bird, J. Dexter III, *"Preliminary Report Joint Army-Navy Rider Block Tagline System DT II E Test,"* EG&G Washington Analytical Services Center, Inc. (Nov 1977).

The joint Army/Navy/Marine Corps Off-Shore Discharge of Containership (OSDOC) Test/Evaluation exercises were conducted in 1970 and 1972 in order to explore various techniques for unloading a containership moored offshore using available commercial and military equipment in an operational environment. A primary problem encountered in the test was the difficulty of accurately placing containers in lighterage due to the uncontrollable swinging of the container (pendulation) from a crane operating on a ship or barge in a seaway. The Rider Block Tagline System (RBTS) has been developed as a viable means of minimizing the sea induced load pendulations, more accurately controlling the radical position of the load with a minimum of boom luffing and reducing the potentially high side loads experienced by cranes afloat.

45. Bird, J. Dexter III and William C. Culpepper, *"Rider Block Tagline Control System Evaluation,"* EG&G Washington Analytical Services Center, Inc. Report TR-D420-001 (Jun 1980).

46. Bird, J. Dexter III, Joseph A. Conte, and William B. Culpepper, *"Rider Block Tagline Electronic Control and Display System,"* EG&G Washington Analytical Services Center, Inc. TR D960-0062 (Apr 1981).

The purpose of this report is to describe the design of the Rider Block Tagline Electronic Control and Display System, explain why certain changes were made from the original prototype design and show, through theory of operation, how it supports the other elements of the RBTS. The report includes a description of the system and its component hardware, a discussion of the electronic circuitry, manufacturers specification sheets and schematics of the electronic control system.

47. Bird, J. Dexter III, *"Motion Compensation for Offshore Container Handling,"* EG&G Washington Analytical Services Center, Inc. (Feb 1986).

This report presents the development and state-of-the-art of motion compensation technology for offshore container handling, particularly those developments that contributed to the success of the prototype motion compensation system installed on T-ACS 1, KEYSTONE STATE. A great deal of historical background has been presented to provide a better understanding of the work accomplished and to provide a firm foundation for future development efforts.
Several conclusions can be drawn from the efforts to date.

1) Motion compensation represents one of the most cost effective methods of providing high-volume, cargo offloading capability in elevated sea states.

2) The use of the Rider Block Tagline System (RBTS) is essential to control pendulation and provides safe and productive cargo transfer in elevated sea states.

3) The RBTS is readily adaptable to a variety of crane configurations, but required special attention to some human factors and design guidelines, outlined in Section II of this report, to assure a successful installation.

4) The Platform Motion Compensator (PMC), in conjunction with the RBTS, can provide container offload capability in Sea State 3 with significant crane ship motions when lighterage can be sheltered in the lee of the crane ship.

5) The Automatic Touchdown and Constant Tension concepts, demonstrated during JLOTS II, provide an effective and viable solution to the complex lighterage interface problem present in elevated sea states.

6) A motion compensation system, integrating the RBTS, PMC, Automatic Touchdown and Constant Tension systems, provides an effective means of meeting the T-ACS operational requirement of 260 containers per day in a Sea State 3 (Fig 2.4).

48. Bird, J. Dexter III, Toni Ann Frizalone, and Charles F. Rushing, *"Platform Motion Compensator (PMC) Advanced Development Model,"* EG&G Washington Analytical Services Center, Inc. TR-W070-0001 (Jul 1983).

This report describes the development, fabrication, and testing of the Platform Motion Compensator (PMC) Advanced Development Model (Figure 2.2). The PMC makes offshore cargo handling possible by compensating for the sea-induced crane platform motions in conditions up to and including Sea State 3. PMC complements the pendulation compensation device, the Rider Block Tagline System (RBTS).

49. Bissonnette, Laurent C., *"Elastometric Impulse Energy Storage and Transfer System,"* Dept. of the Navy, PATENT-4 848 210 (Jul 1989).

50. Blanchet, J., *"Ocean Floor Dredge System Having Pneumohydraulic Means Suitable for Providing Trimming and Heave Compensation Modes,"* Deepsea Ventures, Inc., US, PATENT-4 506 591 (Mar 1985).

There is provided a hoist as for an ocean floor dredging operation, which is capable of providing hydraulic heavy lifting capacity, for raising or lowering the ocean floor, and further can routinely provide the ship heave compensation when lifting capacity is not required, for example during dredging operation, or if the raising of lowering of pipe during pipe deployment and retrieval operations is discontinued for any reason such as extremely high seas. The pneumohydraulic system comprises a piston slidably sealably movable within a cylinder and dividing the cylinder portions and the necessary connections for filling and evacuating one of the cylinder portions with hydraulic fluid without rendering hydraulically inoperative the second portion of the cylinder. A hollow spear extending above the piston head maintains an oil cap sufficient to provide damping capability with the damping means provided.

51. Blasen, R.M., *"Cargo Handling Machine,"* US PATENT-3 341 034 (Sep 1967).

It is a primary object of the instant invention to provide a cargo handling device which is peculiarly adapted to load and unload pelletized or containerized cargo.

It is another object of the instant invention to provide a mobile cargo handling machine which includes a vertically reciprocable elevator. A still further object of the instant invention is to provide a mobile cargo handling machine which may be positioned at the end of a dock and which is provided with a vertically reciprocable elevator means which may descend onto an adjacent vessel or into an open hatch thereof.

52. Bonde, L. and D. Dillon, *"A Concept for Improved Crane Performance In Offshore Operations,"* EG&G Washington Analytical Services Center Report HCG TR 4694-0001 (Sep 1976).

The joint Army/Navy Marine Corps Off-Shore Discharge of Containership I and II (OSDOC I and II) Test/Evaluation exercises were conducted in 1970 and 1972, respectively, in order to explore through test and evaluation various techniques for unloading a containership moored offshore using full-scale equipment in a real environment. The primary difficulty encountered throughout the test was the inability to accurately place the container in the lighter. Two of the problem areas identified were the swinging of a container suspended from a crane operating on a ship or barge in a seaway and the potential for impacts of the container when the crane lowers it onto the deck of a lighter responding independently to the seaway.

This report summarizes various approaches and concepts for controlling container swing and impact caused by wave induced motion and examines the technical feasibility of two specific and promising methods: the rider block tag line system (RBTS) and shock absorbing spreader bar (SASB). From the results of this study, the RBTS and SASB are promising concepts for container

control and impact attenuation when offloading at sea using a conventional revolving boom crane.

53. Bowes, J. F., "*Semi-submersible Platform*," US PATENT-4 909 174 (Mar 20, 1990).

A semi-submersible platform supported on columns with pontoons extending between and outboard of the columns. Damper plates are provided by flat surfaces either on top of the outboard section of the pontoons or by plates positioned on the columns above the pontoons to provide heave and pitch stabilization and motion phase control in relation to the wave action such that when the platform is in the drilling mode the heave phase of the platform is approximately one hundred eighty degrees out of phase with wave action and in the survival mode heave action of the platform is substantially in phase with wave action, such that the platform will ride with the storm waves allowing the use of shorter columns than the current art.

54. Bowes, J. F., "*Semi-submersible Platform*," US PATENT-5 038 702 (Aug 13, 1991).

A semi-submersible platform supported on columns with pontoons extending between and outboard of the columns. Damper plates are provided by flat surfaces either on top of the outboard section of the pontoons or by plates positioned on the columns above the pontoons to provide heave and pitch stabilization and motion phase control in relation to the wave action such that when the platform is in the drilling mode, the heave phase of the platform is approximately one hundred eighty degrees out of phase with wave action, and in the survival mode, heave action of the platform is substantially in phase with wave action, such that the platform will ride with the storm waves alongside the use of shorter columns than the current art.

55. Bretz, G., "*Advanced Cargo Transfer Facility*," in: Offshore Technology Conference Proceedings, OTC Paper 5427 (1987).

Since the planning phase of the Normandy invasion in World War II, the US Navy has been looking for better ways to move cargo across unimproved beaches. In recent years there has been a shift from breakbulk cargo to containers. Because of their larger size and weight, containers have placed additional demands on today's Navy cargo offloading systems. The Advance Cargo Transfer Facility (ACTF) developed by the Naval Civil Engineering Laboratory (NCEL) is a rapidly installed, cargo transfer system which provides berthing for a crane ship and containership. Cranes on the crane ship move containers directly to a pierhead eliminating the need for lighterage. Containers transit from the pierhead to the beach on folding spans supported by jackup foundation modules. Ship mooring is provided by self deploying mooring dolphins. This paper describes the development of this system.

56. Bromell, Raymond J. and John N.J. Sideris, "*Vertical Motion Compensated Crane Apparatus*," US PATENT-4 179 233 (Dec 1979).

Disclosed is a crane employing a fluid cylinder and piston assembly secured to the crane boom and operatively interconnected with the cable between the boom sheave and the load hook to vary the vertical distance between the boom sheave and the load hook in response to relative vertical movement between the crane boom and the platform to or from which a load is to be transferred. Sensors which generate a signal in response to vertical movement are associated with each platform which is movable with respect to a fixed horizontal position. Signals from the sensors are used to control the position of the piston in the cylinder and thereby vary the vertical separation between the hook and the boom in relation to relative vertical movement between the boom and the landing platform.

57. Broome, D. R. and A. Pittaras, *"Ship Motion Prediction,"* Proceedings of the International Offshore Mechanics and Artic Engineering Symposium, Vol. 1, Part A (Feb 18-23, 1990).

The short-term prediction of ship motions has always been of interest to naval architects. Merchant ships and especially warships can achieve a considerable improvement of performance in marine operations, if the ship motions of interest can be predicted for a few seconds ahead. The applications of ship motion prediction include diving bell motion compensation, landing aircraft and helicopters on shops with a reduced risk of accident occurrence, improved missile launching capability and improved seakeeping under certain operating conditions. This paper outlines research work carried out on adaptive ship motion prediction. Adaptive predicators seem to be the optimum solution to the problem of ship motion prediction. Two case studies are included to demonstrate the application of adaptive predictors on shop motion prediction. In the first study, data collected from a model tanker-buoy mooring system are analyzed and surge, sway and yaw predictions are compared to the actual measurements. (Edited author abstract) 9 Refs.

58. Browne, F. D., R. J. Casler, and S. W. Buck, *"Crane Control System Concept Formulation,"* The Charles Stark Draper Laboratory Report R-997 (Sep 1976).

An evaluation is made of two generic, crane-type, cargo handling devices for transferring heavy cargo in moderate sea states. Both modified conventional sea cranes and mechanical arms are considered in the study. The advantages and disadvantages of each type of device are outlined in a qualitative manner. Control system implementations and structural limitations are emphasized. With the limited analysis that has been performed thus far, the crane configurations have been rated, on a preliminary basis in terms of overall desirability for use as cargo transfer devices in Sea State 3 as follows: (1) conventional sea crane with auxiliary taglines, (2) conventional crane with hydraulic arm, (3) wireless hydraulic arm, and (4) hybrid hydraulic arm.

59. Browne, R., R. Cassler, and E. Foster, *"Preliminary Control System Design for a Conventional Crane Cargo Transfer System Operating in Moderate Seas (Interim Report),"* The Charles Stark Draper Laboratory Report C-4724 (Sep 1976).

The preliminary design of a control system that improves the cargo transfer capability of conventional cranes in moderate seas is presented. The control system consists of a tagline tension control system, to alleviate load swinging, and a semi-automatic "touchdown" control system. All aspects of the mechanical actuator design as well as the feedback systems design are presented. Numerical simulation of the control system dynamics is also discussed.

60. Brun, Andre G., *"Process And Apparatus For Transfer Of Cargo At Sea,"* US PATENT-4 174 188 (Nov 1979).

The invention is directed to a method and apparatus for considerably reducing the risks of collision between cargo and ship during transfer of the cargo at sea. For this purpose, there is created in a short interval of time a sufficient space between cargo and the ship by lowering of the upper part of a support at the moment when the cable lifts the cargo from the support. The invention also applies to transfer of cargo from a wharf.

61. Budal, K., *"Floating Structure with Heave Motion Reduced by Force Compensation,"* International Offshore Mechanics and Artic Engineering Symposium, 4th, Vol. 1, pp.92-101 (Feb 17-21, 1985).

A floating structure with small vertical motions is described. The structure consists of a floating body fixed to a fully submerged body. The wave forces on these bodies compensate each other over a fairly large frequency interval. As a result the net force on the structure as a whole is small, resulting in a correspondingly small vertical motion. Criteria for obtaining force-compensation are given. Experimental results for a model of a ship-like structure are presented. The device may have applications in offshore engineering and also in wave energy utilization. 6 Refs.

62. Burke, Ben G., *"Downtime Evaluation for Operations from Floating Vessels in Waves,"* NAME (May 1977).

Methods are described for evaluating downtime for a variety of in-ocean operations from floating vessels in waves. Downtime estimates are determined from the motion response of the vessel in waves, the motion parameters and limits associated with operations to be performed, and the wave conditions to be encountered.

Considerations for implementing the methods are discussed and examples from evaluation of exploratory oil drilling, VLCC tankerlightering, and crane barge operations are presented. Also, a simplified model for motions of full-form ships in waves, which has proven to produce useful results, is described.

Results from a downtime analysis provide quantitative measures for evaluating feasibility of operations, relative benefits of alternative vessels, and the effectiveness of operating time. The development of further data on significant parameters and limits for oil drilling and other operations would improve the effectiveness of the methods.

63. Caldwell, Joseph M., James L. Baker, *"Mobile/Portable Ports 1990,"* U.S. Army Advanced Materiel Concepts Agency Report No. AMCA-71-009 (Mar 1971)

Container ships and other new configurations of ocean-going cargo ships present new problems in the construction and operation of ports in areas where sophisticated port facilities do not exist. Present mobile or portable port equipment lacks the necessary deployability and cargo handling capability to deal with these new problems. The technology which could lead to the future realization of a truly mobile or portable port is explored and evaluated in this report. A mobile or portable port is defined; a brief technological history of portable ports provided; the Army's need for such a port discussed; and overall configuration design considerations listed. Proposed types of facilities and equipment for transferring cargo, including containers, ashore are individually discussed in terms of their future potential for mobile/ portable port use. Known schemes for mobile or portable breakwaters are characterized, described, and evaluated. The creation of artificial inshore harbors is presented for possible utilization in a mobile or portable port. Equipment concepts having the most potential for utilization in a future mobile/portable port are identified and future port equipment development recommendations are made.

64. Casler, R., F. Browne, E. Foster, J. Eterno, and W. Podgorski, *"The Design of Control Systems to Aid Cargo-Transfer Operations in Moderate Seas (Final),"* C.S. Draper Laboratory Report R-1018 (Dec 1976).

65. Cecce, Robert F., *"Study to Determine the Feasibility of Installing a Rider Block System on Manitowoc 4100W Ringer Cranes and P & H 6250 Cranes,"* Epoch Engineering Report No. 361-1 (Mar 1977).

66. Chalmers, H. and R. Sanders, *"Motion Compensation Deck Handling System for the Remote Unmanned Work System,"* ASME Paper, No. 80-WA/OCE-11, Nov 16-21, 1980, pp. 14. (Nov 1980).

The paper provides a detailed description of the Motion Compensation Deck Handling System of the Remote Unmanned Work System. It cites goals, describes its special features, and discusses the major problems encountered and lessons learned during its checkout and ocean testing.

67. Chambers, H.B., *"Motion Takeup Device,"* US PATENT-3 512 657 (May 1970).

The mechanism is normally contracted or telescoped and extends when manually pulled. The amount of extension is at least equal to the height of a wave from crest to valley. In this fashion the mechanism can be extended to accommodate the motion, due to waves, of a boat or barge being unloaded. Once the manual pull is released, the mechanism contracts when the upward motion of the load connected to it permits, and has a check device that then functions to prevent extension when under load. The mechanism permits hook-up of the load when the load is moving downwardly on a wave and permits hoisting of the load without jerking when the load is moving upwardly on a wave, or when the load reaches the crest of wave.

68. Chang, Nuke Ming, *"Motion Control System,"* US PATENT-3 642 783 (Nov 1971).

Disclosed is an open loop control for maintaining constant tension in a cable connecting two bodies. Among the applications of the system are transfer of a load between a pier and a vessel or between two vessels, maintaining constant tension in a cable between two vessels, barge towing, underwater pipe laying, etc. The system includes a motion sensor, and a motion-compensator subsystem to generate a control signal in synchronism with the motion being sensed but at a fixed phase offset in relation thereto. The control signal operates a motor or the like at a fixed speed forward or reverse to compensate for the sensed motion with phase offset compensating for the reversal time lag between full speed in opposite directions present in the motor system.

69. Charles Stark Draper Laboratory, Inc., *"Final Development Report For The Motion-Compensated Crane,"* Charles Stark Draper Laboratory Report R-1424 (Dec 1980).

This report addresses the design and testing of an Automatic Cargo Landing System (ACLS) based on the control technique presented in Section 1.4. Work began in April 1979, and the ACLS was completed and ready for shipment to the test site at the beginning of February 1980. Researchers spent two weeks testing the system at Port Hueneme, California, during February 1980. This report describes the ACLS design, the hardware and control algorithms, and the system tests. It also reports the test results and suggests improvements to the system based on those results.

70. Charrett, D.E. and A.M. Hyden, *"Dynamic Factors for Offshore Cranes,"* Offshore Technology Conference, Dallas, TX (1976).

71. Chou, F.S., D.P. Tuturea, and G.J. Blight, *"Apparatus to Reduce Vessel Motions,"* Brown and Root, Inc., US PATENT-4 232 623 (Nov 1980).

The invention relates to apparatus for reducing the intensity of waves reflected from the vessel. According to the invention, the vessel is provided with at least two specially designed tanks or cavities, one on the starboard side of the vessel and one on the port side of the vessel. The tanks

extend above and below the mean water line of the vessel. In one embodiment of the invention, each tank has a bottom plate which extends substantially laterally outward from at least a portion of the bottom of the vessel and which is freely accessible to the surrounding water; vertically aligned, traversely extending outwardly directed, perforated plates which are spaced apart along a longitudinal length of the tank, and a vertically aligned, longitudinally extending perforated plate or bulkhead which is spaced apart from the vessel along a longitudinal length of the tank. In other embodiments, more than one perforated longitudinally extending bulkhead or baffle is provided between the bottom plate and a laterally extending upper member to further reduce the intensity of waves reflected from the vessel. In another aspect of the invention, buoyancy chambers may be provided to counterbalance the weight added by the perforated plates, bulkheads, and the bottom plate. In yet another aspect of the invention, only longitudinal bulkheads are used in combination with the buoyancy chambers to reduce the relative motion of the vessel.

72. Cipkowski, Jerome T., *"Loading-Unloading Capability for Cargo Box Transport Vehicle,"* Dept. of the Navy, PATENT-4 153 169 (May 1979).

73. Clarkson, J.A. and F.M. Kenny, *"Offshore Crane Dynamics,"* in: Offshore Technology Conference Proceedings, OTC Paper 803,793 (1980).

The environment in which offshore cranes operate generate a number of factors which determine that the loadings on the structure are essentially dynamic in nature and not static as has been commonly used in design in the past. This paper presents the nonlinear equations of dynamic equilibrium and a method of solving these equations. From the theory developed a typical crane is analyzed and the general trends of behavior are discussed.

74. Claassen, Josephus A.M., *"Device For Lowering A Load, For Example, A Diving Bell From A Vessel From A Spot Above The Water Level To A Spot Beneath The Water Level,"* US PATENT-4 155 538 (May 1979).

A device for lowering a load, for example a diving bell from a vessel from a spot above the water line to a spot beneath the water line, comprising a winch and a cable connected with the load and moved by said winch along at least one cable pulley rotatable about a shaft. In order to prevent that the cable becomes alternately slack and taut during contact of the load with water, it is proposed to constantly maintain the taut state of the cable by placing the shaft of the pulley parallel to itself and connecting it with the plunger rod of a plunger cylinder provided with an accumulator.

75. Cobb, A. Donn, *"Hydroways,"* Dept. of the Navy, US PATENT-4 042 904 (Aug 1977).

76. Cohen, J. and A.M. Loeb, *"Mathematical Analysis and Digital Computer Program for Simulation of the Underway Replenishment-at-Sea System,"* NAVSECPHILADIV Project Rept FT-3195 (Jan 1974).

77. Cojean, Maurice and Jean-Paul Colin, *"Device For Removing And Depositing Loads Between Two Supports In Repeated Relative Vertical Movement,"* US PATENT-4 324 385 (Apr 1982).

The invention relates to a device for removal and deposition of loads between two supports in repeated relative vertical movement. The device consists essentially of a crane close to the high point of the support on which said load rests in its rising movement for lifting the load. To do

this, the lifting device suspended from the hook of the lifting crane comprises a structure supporting a winch, a detection device for the winding in or out of the cable wound by said cable when its winding ceases momentarily, that is to say when the speed of lifting of the crane is equal to the decreasing speed of heaving of the support. The device is applicable to the unloading of ships supplying off-shore platforms.

78. Columbia Research Corporation, *"Container Offloading and Transfer System (COTS), Temporary Container Discharge Facility (TCDF), Motion Compensation System (MCS), System Design,"* Volume I (Oct 1980).

This report documents the efforts in the design of a Motion Compensation System (MCS) for the Container Offloading and Transfer System - Temporary Container Discharge Facility (COTS-TCDF), up to the time those efforts were terminated by a contract modification resulting from program funding changes. The MCS is an add-on system to the basic Manitowoc 4100W Ringer Crane, with the NCSC-developed Rider Block Tagline System (RBTS) incorporated, which was selected for system development. The hardware/software system provides for simplified operator control of the basic crane, the RBTS, and additional manual and automatic load control functions developed as part of the systems design effort. The MCS containerized cargo offloading and retrograde operations at a specific rate of 10 containers per hour between environment up to and including sea state 3, while automatically compensating for the effects of both relative ship motions and sea-induced motions on the crane-borne load.

79. Columbia Research Corporation, *"Installation and Checkout of the Rider Block Tagline System (RBTS) TECHEVAL and OPEVAL of the Temporary Container Discharge Facility (TCDF) with RBTS,"* (Mar 1981).

This report describes the installation and checkout of the Rider Block Tagline System (RBTS) and training for its operation and maintenance. The RBTS is a crane-mounted, powered tagline system designed to prevent load pendulation and boom sideloads while operating in a dynamic environment. The RBTS was installed on the Manitowoc 4100W Crawler Crane used in the Container Offloading and Transfer System/Temporary Container Discharge Facility (COTS/TCDF). The RBTS installation, checkout, and training was accomplished between 10 October and 10 November 1980 near San Diego, CA. The RBTS was installed with minimum difficulty. However, a number of problems were encountered during the checkout and calibration of the system. These problems were resolved and the system operated as designed. Five Navy crane operators received 2 days of classroom instruction and 10 hours of hands-on RBTS training. A Navy electronics technician and 2 construction mechanics received 2 days classroom instruction on the RBTS theory and operation. The technician also received on-the-job training and the mechanics preformed routine maintenance on the RBTS.

80. Columbia Research Corporation, *"Sea Tests Barge Characteristics and Rider Block Tagline System (RBTS) Proof Tests S1 through S3 and S4B, S4C, S4D for Container Offloading and Transfer System (COTS),"* (May 30, 1980).

81. Columbia Research Corporation, *"Tension Envelope of Rider Block Tagline System (RBTS) Container Offloading and Transfer System (COTS),"* (undated).

82. COMOPTEVFOR, *"Operational Evaluation of the Temporary Container Discharge Facility,"* (Apr 2, 1981).

This report provides details of operational effectiveness and operational suitability determination

of the Temporary Container Discharge Facility (TCDF) section of Container Offshore Transfer System (COTS). The TCDF has the potential to be operationally effective in seas up to and including state 3, given that an effective, representative platform subsystem is provided. The TCDF has the potential to be operationally suitable pending resolution of: (1) Inadequacies in the training plan, (2) Indefinite crane operating limits, and (3) Suitability of proposed TCDF platforms. TCDF is not recommended for approval for service use. It is recommended for provisional approval for service use after successful completion of the following: (1) Development of crane operating limits as functions of hookload, reach, and vessel motion. These limits should be published for each proposed ship platform and should be defined as safe working limits. (2) Upgrading the MANITOWOC 4100W Series III Ringer Crane with additional counterweights and a heavy duty train system. (3) Improving RBTS reliability. (4) Conducting at-sea testing on a representative platform.

83. Cook, R.G., *"Buffer System for Ships,"* North American Rockwell Corporation, US PATENT-3 585 959 (Jun 1971).

This invention relates to a buffer system that maintains adequate separation of two ships in an alongside mooring configuration; and will accommodate the relative motions of the two ships in a rough sea, to prevent the hulls from impacting. A plurality of inflated tires are biased in an outwardly movable direction to maintain the desired spacing; and these yield in a controlled manner that is established by inflation pressure, snubber design, mechanical linkage, and the like.

84. Crane, J. W. and C. M. Claudio, *"A Statistical Study of a Load Touchdown Algorithm for Use on The Test Bed Barge, JR-1,"* Naval Coastal Systems Center Technical Note 720-84 (Apr 1984).

85. Crenshaw, R.S. Jr., *"Constant Tension Device For Boat Falls,"* US PATENT-2 948 512 (Aug 1960).

This invention relates generally to hoisting equipment and more particularly to apparatus for and methods of providing a substantially constant tension for wire falls and the like, which are required to operate under conditions, such as those encountered in the launching and retrieving of small craft in rough seas, where the load is capable of experiencing sudden and irregular movement.

86. Crowely, W.A., *"Stable Multiple-Chamber Air Cushion Boat Hull,"* US PATENT-3 742 888 (Jul 1973).

A soft riding, stable multiple-chamber air cushion boat hull having a plurality of high pressure air chambers around the periphery automatically providing heave stability as well as roll and pitch stability. The hull may further include a vent slot providing a means for exhausting the spill out of the continuously charged high pressure chambers and further makes a sharp reduction in the bow wave pressure. In addition to providing stability, the high pressure chambers lift the boat providing a low friction, soft riding air cushion support.

87. Culpepper, William B., *"The Assessment of Damage to the T-ACS Rider Block Tagline Systems,"* Columbia Research Corporation (Aug 1985).

During exercises of the T-ACS, components of the RBTS were structurally damaged. The objective of this report is to determine if the observed damage was the result of improper operation or of design inadequacy.

88. D'Auriac, P.A., *"Shock Absorber For Docking Ships,"* US PATENT-2 842 939 (July 1958).

This invention relates to a shock absorber for taking the impact of ships and other vessels in docking and mooring thereof.

The shock absorber of the invention is characterized in that it comprises two impact receiving elements disposed in substantially the same horizontal plane and which are movable apart upon receiving the impact by pivoting in their respective supports on substantially vertical axes.

89. Daskin, Mark S. and M. R. Schulthesis, *"Models of Lightening Operations,"* Final Report (Sep 1980 - May 1982).

90. David Taylor Naval Ship Research and Development Center, *"Merchant Shipping and Transfer Craft Requirements in Support of Amphibious Operations,"* (Apr 1977).

The use of merchant ships to supplement Navy ships in filling the lift requirements in transporting the assault follow-on echelon of a Marine Amphibious Force during amphibious operations has been analyzed. The analysis was based on detailed characteristics and loading/unloading operations of the merchant ships in both in-port and over-the-beach situations. It included consideration, in the over-the-beach operations, of ship unloading platforms, transfer craft, and cargo handling devices ashore.

Two computer models were used to simulate these operations. Results indicated that, although container ships are generally highly productive, the long lead times required before they are available and their complex unloading requirements decrease their productivity in over-the-beach operations. Breakbulk ships are less productive but are largely self-sustaining, except that they require transfer craft for unloading. RoRo ships and barge carriers are highly productive and generally can be made self-sufficient but are in limited numbers.

91. Davis, D.A. and H.S. Zwibel, *"The Motion of Floating Advanced Base Components in Shoal Water - A Comparison Between Theory and Field Test Data,"* NCEL Report N-1371 (Jan 1975).

As part of the Navy's program to develop mobile port facilities, an analytical model has been developed to compute the relative motion between vessels in regular and random seas. The model, which considers all six degrees of vessel motion, is based on strip theory and is suitable for analyzing all single hull, linearly moored vessels. Ship motion and wave data obtained during recent offshore discharge of containership II (OSDOC II) field tests were used to validate the model. The results presented herein suggest that the model closely predicts the absolute motion of ocean going vessels (2,000 tons and larger), but that its predictions of lighter motions when the lighters are in close proximity to larger craft are less accurate. The probable cause of this disparity is hydrodynamic interaction, an effect which is not presently considered in the model.

92. Davis, D.A. and J.J. Traffalis, *"OSDOC II Crane Platform Productivity as a Function of Sea State,"* NCEL Report TM-55-77-6 (Jul 1977).

A study was made of OSDOC II crane platform productivity as a function of sea state. The approach employed the CEL developed RELMO computer program fortified with engineering judgements based on field test data, OSDOC II experience and other available crane operational data as they applied.

Considering the approach used in this investigation and the restraints imposed by the paucity of the OSDOC II and post-OSDOC II field test data, the following findings and conclusions are justified: (1) The time for motion sensitive phases of container transfer, i.e., spreader bar into containership cell and MILVAN onto lighter well deck, increases with increased relative vertical motion between the crane boom tip and containership cell or lighter well deck; (2) Evidence from post-OSDOC II tests indicate that unskilled crews can be expected to take 1.8 to 2.3 times longer to cycle containers under OSDOC type operations at sea depending, respectively, whether short boom or long boom cranes are used; (3) The crane onboard containership (COD) is the least affected by increased sea state conditions of the three CDF systems analyzed; (4) For the LST in quartering and beam seas, the dominant vertical component of motion between the crane boom tip and containership cell and between the crane boom tip and lighter well deck is the vertical roll component of the crane boom; (5) Sustained unloading productivity estimates indicate only slight differences in performance for the FDL and LST platforms when offloading a C5 Class containership; (6) Productivity of the FDL crane platform is slightly less when offloading the larger and more hydrodynamically stable C7 Class containership. This is due to the greater reach of the FDL crane when offloading the C5, resulting in an increase in the roll induced vertical component of crane boom tip motion (the dominant component of motion); and (7), Narrow-banded swell (having a sufficiently high energy content) with a dominant period around the natural roll period of any crane platform will seriously degrade - if not altogether prevent - cargo handling operations.

93. Davis, D.A. and J.E. Kasunich, *"Static And Dynamic Stability of Crane Platforms,"* NCEL Report 55-75-07 (Mar 1975).

The unloading of deck-stacked or cell-stored containers into the receiving lighterage is perhaps the most critical phase in the cargo transfer operation. Wave induced motion can cause large crane boom displacements regardless of whether the crane used to unload containerized cargo is located on the containership or is operating from a floating platform moored alongside. Excessive motion of crane booms results in load pendulation, lack of control in container placement aboard lighters, and unacceptable levels of container and lighter damage due to load impact. It is this critical problem of crane platform motion which is the subject of this study.

94. Davis, D.A., *"Static and Dynamic Stability of Navy Lightered (NL) Pontoon Causeways,"* NCEL Report TM 55-77-4 (Jun 1977).

A study was made of the static and dynamic stability of single-section and three-section end-linked Navy Lightered (NL) pontoon causeways which are an important class of lighterage in the Navy's advanced base logistics program. Roll, the critical component of causeway motion, was computed for various conditions of deck loading. In all cases studied, waves were assumed to be incident beam-on to the causeways. Graphs, specifying maximum loads which can be safely carried in given states of sea, are presented. These graphs should aid planners of causeway lighterage operations.

95. Delago, P.C., *"Heave Motion Compensation Apparatus,"* American Hoist & Derrick Company, US PATENT-4 448 396 (May 1984).

A heave motion compensation apparatus is used to move a load from a supply ship in heavy seas to a platform on a oil rig. A main load line extending down from a point of a crane boom mounted on the oil rig is driven by a pair of hydraulic main hoist drum motors. One of the motors is a variable displacement swash-plate type motor. The motors are driven through a hydrostatic transmission by a pair of variable displacement hydraulic pumps. A signal line

running over the boom point is attached to the supply vessel and maintained taut. Sensor and control means reading movement of the signal line with respect to the first platform is used to control the displacement of one of the main hoist pumps to cause an outer end of the main hoist pumps to cause and outer end of the main hoist line to move up and down with the supply vessel. The other pump is controlled to raise and lower the outer end of the main load line. The main load line is attached to the load. A signal is generated by the sensor and control means to indicate upward movement of the outer end of the main load line, and this signal is used to generate a signal representative of the rate of change of the speed of the outer load line and the load attached thereto. On demand by the operator, the control means determines when the supply vessel is moving up with respect to the oil rig and the rate of change of velocity is zero. The control means then moves the variable displacement main hoist drum motor and the two variable displacement main hoist pumps to maximum displacement to cause the main load line to pick the load from the supply vessel.

96. Dillon, Richard H.F., *"Self-Propelled Vehicle System For Use In Transfer Of Materials,"* US PATENT-3 707 922 (Jan 1973).

A ship-to-ship or ship-to-shore material conveying system comprises a load line extending between a supply station and a receiving station and means for keeping the load line under substantially constant tension. A self-propelled load carrying vehicle is arranged to travel along the load line and has means for reducing impact between the vehicle and once of the stations which may move with respect to the other.

97. Dobeck, Gerry J., *"Control System Analysis for COTS Crane-On-Deck Configuration,"* NCSC TR-360-81 (Jun 1981).

A feasibility study of using a modified commercial crane to transfer cargo between ships in a moderate seaway is presented. The critical choice of sea spectra for design and analysis is presented. Speed drag taglines and fixed length taglines are investigated for reducing horizontal load pendulation. Results are compiled in a nondimensional form for extrapolation to different load weights, loadline lengths, and seaway frequencies. Results of a complete nonlinear simulation are given showing all systems operating simultaneously.

98. Doe, T.B., *"Power Transmission,"* US PATENT-2 249 947 (Jul 1941).

This invention relates to power transmissions and more particularly to a novel power transmission device and control therefor particularly adapted to hoisting an object while relative movement between the object and the hoisting device is occurring. A device of this character is useful, for example, on ship board for the purpose of lifting floating objects such as boats, airplanes, etc., from a rough sea. The invention is shown and described as adapted for this use, although it will be understood that the invention may be used for other purposes.

99. Dougherty, Edmond J., Donald E. Lee, Paul D. Shively, *"Automated All-Weather Cargo Transfer System,"* NAME (Apr 1969).

The purpose of this report is to define a concept for an advanced cargo handling system for offshore transfer of cargo under sea state 3 conditions or higher in a Logistics Over The Shore (LOTS) environment. The concept, called the Automated All-Weather Cargo Transfer System (AACTS), employs robotic materials handling techniques and a unique method to stabilize the ship/lighter interface. It is projected that the system will have a sea state 3 capability of 600

containers per day. In calm seas, a rate of approximately 1,800 containers per day is estimated. The system would offload/load two ships and four lighters concurrently. It is estimated that the system would require only about 30 Army personnel for operation. The design uses four B Delong barges as a platform for a large transverse frame. The frame encompasses a number of container manipulators with intelligent spreader bars, a conveyor system, and electrohydraulic/pneumatic actuators (having six degrees of freedom capabilities). The system is operated by an automated control system. Interface subsystems, known as berthing modules, would be capable of moving in synchronism with a craft. A linear array of such modules would provide a soft docking for vessels and could also be used to warp and rapidly cast off a vessel.

100. Drelicharz, Joseph A., *"Hydrodynamic Response of AMMI Causeway in the Surf Zone - VLAP,"* NCEL Report TN-1052 (Jan 1970).

Dynamic response of a light-weight, highly buoyant system can also produce critical problems in operations where relative motions between pontoon pier and ship, and pontoon barge and ship can be anticipated. Since a possibility of damage is inherent in such systems and because the tendency for future systems is toward lightweight materials and construction, pilot tests should be made to determine the dynamic response characteristics of pontoon systems. Such a study has been concluded at NCEL, modeling the lightweight AMMI pontoons; its description and results are presented in this paper. The study is limited in scope and application and, therefore, further studies with other pontoon systems are necessary before the results can be used in developing an analytical response solution for general operating conditions.

101. Drummer, Robert E., *"Marine Crane Lifting Control,"* US PATENT-4 304 337 (Dec 1981).

A marine crane includes a high speed winch having a hydraulic heave compensating system that automatically controls the crane winch to compensate for the vertical movement of a load during off-loading operations. The heave compensating system includes a reversing valve for overriding manual control and for directing control pressure to stroke the pump of a hydrostatic winch drive into its raise mode of operation, and a compensating valve that regulates the displacement of the pump permitting it to develop and maintain only a predetermined pressure in the high pressure main fluid line. The heave compensating system preferably includes a lift control system for automatically hoisting a heaving load only at or near the crest or trough of a wave.

102. D'Souza, R., and M.C. Chen, *"Non-Linear Flexible Mooring System Design for a Lightening Operation,"* American Society of Mechanical Engineers (1987).

This paper presents a simple and cost effective technique for the non-linear dynamic analysis of relative slow drift motions between flexibly moored floating vessels. It includes a brief overview of the phenomenon of wave drift and discusses procedures for generating slowly varying drift force time histories. The techniques are illustrated by the application to a lightening operation involving a shuttle tanker that is offloading crude oil from a single point moored storage tanker to which it is flexibly interconnected via synthetic hawsers.

103. Duncan, J.H., R.H. Barr, and Y.Z. Liu, *"Computation of the Coupled Response of Two Bodies in a Seaway,"* paper presented at International Workshop on Ship and Platform Motions, UC-Berkeley (Oct 26-28, 1983).

This paper describes a linear, frequency domain method for calculating wave induced, zero speed motions of two closely spaced, hydrodynamically interacting bodies of arbitrary geometry. These

bodies may be connected to each other and/or to the ocean bottom. The computational methods used to calculate hydrodynamic forces are similar to several other published methods, but incorporate a detailed treatment of complex body-body connection systems and use a preprocessor program to automate body surface paneling. Calculated results are presented for an example of ship-to-barge lightering or cargo transfer in shallow water. These results illustrate the profound effect of wave heading angle relative to the two bodies.

104. *"DynaCraft Intervention System,"* Scand. Oil-Gas Magazin, Vol. 17, No. 1-2, pp. 76-77 (1989.

A Light Subsea Intervention System (LSIS), developed by DynaCraft, is described. The system is designed to be mounted on floating vessels and to be capable of positioning tools or modules on a subsea installation. LSIS employs active heave compensation to keep the load still while the vessel undergoes wave induced motions.

105. Egeberg, Lansing E., *"Motion Compensating Device for Supported Underwater Structures,"* Dept. of the Navy, US PATENT-3 807 334 (Apr 1974).

A stable platform for handling small submersibles and other underwater apparatus from the surface employs a self-reeling buoyant winch to isolate the platform from surface motion. A ballasting arrangement is controlled from the surface to recover the platform and its load without platform or vehicle manipulation. The deck recovery boom and winch arrangement permit the platform to be placed on the deck for on-and-off loading.

106. E. G. Frankel, Inc., *"Development of a Conceptual Design for Container Discharge Facility,"* Final Report, E. G. Frankel, Inc. Report No. 1039 (Apr 15, 1972).

107. Eik, Geir, *"Method For Setting Down Or Taking Up A Load From Or Upon A Loading Location By Means Of A Crane And An Apparatus For Carrying Out The Method,"* US PATENT-4 147 330 (Apr 1979).

In a method and an apparatus for putting down or taking up a load from or upon a loading location by way of a crane, wherein the crane or the loading location is subjected to substantially irregular vertical movements which change the distance between the hoisting hook of the crane and the loading location, there is accomplished a preferably continuous measuring of values which give more information about the distance and relative velocity between a point on the crane and the loading location. The measuring signals are treated and possibly converted so as to create regulating signals which influence the velocity of the hoisting hook and/or the position of the crane to impart to the hoisting hook an acceleration or retardation as a compensation for the said irregular movements, so that the relative movement between the load and the loading place will follow the course desired by the operator, without undesired powerful collisions between the load and the loading location.

108. Elling, R. E. and A. T. McClinton, *"Dynamic Loading of Shipboard Cranes,"* Ocean '73 IEEE International Conference on Engineering in Ocean Environment, pp. 174-7 (1973).

Equations of motion are derived for a simple model of a mass suspended by cable from a crane attached to a ship which has arbitrary prescribed motion. The response of the mass is determined, through numerical integration of the differential equations of motion, for a typical ship motion and for a range of cable lengths and rates of change of cable length. Large response angles of oscillation are seen to develop for certain critical lengths of cable. Reduction of response motion

appears to be made possible through careful control of mass deployment of retrieval velocities.

109. El-Tahan, H.W. and D. Howard, *"Offshore Testing of a Personnel Transfer System,"* Arctec Newfoundland Ltd., Presented at the 20th Annual Offshore Technology Conference (May 1988).

The Personnel Transfer System (PTS) has been designed to transfer personnel between an offshore drilling unit and a standby (supply) vessel for everyday use as well as emergency evacuation. The PTS consists of a transfer device which is a rigid structure that protects its occupants and survives vertical drops and lateral impact and a guiding system between the transfer device and the standby vessel.

This paper presents the result of an offshore testing program carried out in August 1987 to evaluate the performance of the PTS during transfers between the Bow Drill III drill rig and the Trinity Bay standby vessel that was operating on the Grand Banks of Newfoundla..

The main objectives of the offshore tests were to test the prototype PTS under actual offshore environmental conditions, collect data needed to establish the safe operating limits and evaluate the effectiveness of the Positive Control System that guides the PTS during landing on the standby vessel.

The Transfer System was extensively instrumented with accelerometers, inclinometers, load cells and motion sensing packages. A simulated "occupant" was instrumented with an accelerometer. The standby vessel was also instrumented with a motion package. In addition, three video cameras located on the drill rig and the standby vessel were used to record all the tests.

110. Essoglou, Milon E., *"Army-Navy Test of Offshore Discharge of Containership OSDOC I 5-9 December 1970,"* Naval Facilities Engineering Command (Jul 1971).

The Department of the Army, with Department of the Navy participation, conducted an evaluation/observation of offshore discharge of containerships in a sea environment. This exercise was initiated by the Army to test present-day operational techniques, with available equipment, for handling containers. Headquarters, U.S. Army Transportation Center, Fort Eustis, was tasked with the test that took place on 5-9 December 1970.

111. Eterno, John S. and Richard J. Casler, Jr., "Adaptive Cargo Landing System," US PATENT-4 136 391 (Jan 1979).

An adaptive cargo landing system for landing a load from a support on a first vessel or platform to a deck on a second vessel or platform, where the distance between the support and deck is a bandwidth limited random time function. A variable gain controller is arranged in a feedback loop with a load position actuator and load position sensors to be increasingly responsive to the load-deck relative position and motion as the load approaches the deck.

112. Fang, M.C., C.H. Kim, *"The Lateral Drifting Forces and Moments on Two Ships in Proximity in Waves,"* International Conference on Offshore Mechanics and Artic Engineering Proceedings, Vol. 2 (1989).

An analytical procedure for evaluating the lateral drifting forces and moments between two ships in oblique waves by nearfeild method is presented in this paper. The velocity potential, including the hydrodynamic interactions are evaluated by a two-dimensional sink-source technique. Then the strip theory is applied to calculate the sectional force and the drifting forces and moments of the whole ships can be obtained by Simpson rules. Four components of the mean drifting force

are obtained, in which, the relative wave term is dominant, whereas the Bernoulli quadratic component is secondary. The negative drifting force is observed at some frequency for the ship which is in the weather side of the wave. The lateral drifting force even occurs while the ships are in the head or following seas, which is consistent with the real physical phenomena at sea. The present technique offers the theoretical explanation for nonlinear phenomena between two ships in waves and will be helpful for the future practical study in random waves.

113. Faller, F. R., R. G. Clouston, and L. Bergholz, *"Motion Compensation Means For A Floating Production System,"* US PATENT-4 625 673 (Dec 2, 1986).

There is disclosed an apparatus for providing passive motion compensation at the ship-riser interface of a rise-moored floating production system or oil storage tanker, with its associated equipment including a riser handling system. Normal production proceeds, while ship motions are isolated from the riser, preventing excessive load transfer or unacceptable dynamic effects. The main feature of the system is its ship-borne installation, with all moving parts clear of the waterline. The system is totally self-contained, with motion compensation, riser pipe and handling equipment on board. By installing the flotation within the hull of the ship, it moves with the ship, thus avoiding significant inertial and weather-related loads. The design is flexible. The range of sea can be extended by adjusting the basic parameters: Float shape and size, tank depth, liquid S.G., counterweight size, link geometry, bridge length, etc.

114. Foley, Edward W., *"Relative Motion Measurement During Interface Operations Between the USS SPIEGEL GROVE (LSD-32) and the JEFF CRAFT,"* DTRC SPD-0943-02 (Oct 1980).

This report describes trials that were conducted onboard the USS SPIEGEL GROVE (LSD-32) involving the interfacing of the LSD-28 Class with the experimental amphibious assault landing craft designated the JEFF CRAFT. Currently, two configurations of the air cushion JEFF CRAFT are undergoing evaluation by the Navy. JEFF (A) was not in full readiness for the interface trials, and only participated in a limited fashion. JEFF (B) was the primary test vehicle which successfully negotiated entries and exits from the LSD well area with the LSD at anchor in protected waters and underway in the Gulf of Mexico. The interface trial effort involved many technology groups studying various aspects of the interface operations. The aspect of concern in this report is the relative motions between the LSD and the JEFF CRAFT as they came into close proximity. More specifically, this effort was to define the relative motions that might result in collision or impact between craft and ship. During the at sea evaluations, sea conditions remained very benign such that relative motions were limited to horizontal plane motions and no impacts or collisions were noted.

115. Ford, Bacon & Davis Engineers (for NCEL), *"Report, Survey of Cranes Suitable for Use in a Temporary Container Discharge Facility,"* Vol. I - Test and Exhibits, Vol II - Appendix (Nov 30, 1976).

116. Frankel, E.G., A.W. Johnsen, A.A. Padis, and G.F. Doyle, *"Conversion of Delong Pier Barge Type B to Floating Container Discharge Facility,"* E.G. Frankel Inc. (Jun - Oct 1973).

The report discusses the feasibility of and the requirements for the conversion of a Delong Pier Barge Type B to a floating Container Discharge Facility (CDF) having as its primary and secondary missions respectively, the discharge of containers from nonself-sustaining containerships and the discharge of general cargo and special purpose ships to lighterage or other modes of waterborne and/or air transport in Logistics-Over-The-Shore (LOTS) type operations. A tertiary mission of the CDF, as specified in the Purchase Description, entails the transporting of limited

quantities of cargo handling equipment, portable port equipment, small lighterage, and other cargo to the scene of its operations while under tow.

117. Frankel, E. G., *"Low Cost Ports for Developing Countries: The Role and Economics of Ro-Ro Operations,"* BML Business Meetings Ltd (May 9-11, 1984).

RoRo transport offers significant advantages for developing countries, but changes in the interface technology are required to render it more effective under prevailing conditions in many developing country ports. A discussion is given on the following topics: cargo transfer facilities; floating ramp system for interface with lighters; floating or floatable/relocatable bridge spans or ramps; semi-submerged catamaran terminals; and relative motion in partially exposed locations.

118. Frankel, E.G., A.W. Johnsen, and A.A. Padis, *"Feasibility of Using Commercial Offshore Drilling Platforms as a Container Discharge Facility,"* E.G. Frankel Inc. (Jun - Oct 1973).

The report describes the conceptual studies and evaluation of the conversion and use of commercially available offshore drilling rigs, platforms, vessels, and self-elevating rigs, for operation as a Container Discharge Facility (CDF). It has as its primary and secondary mission, respectively, the discharge of general cargo from general nonself-sustaining containerships and the discharge of general cargo from general cargo and special purpose ships to lighterage of other modes of air and/or waterborne transport in Logistics-Over-The-Shore (LOTS) type operations. The report covers the technical and operational details of drilling rigs, platforms, vessels, and self elevating rigs available of under construction in June 1973 and discusses the feasibility of such conversion and resulting conversion requirements and costs.

119. Franklin Research Center, *"Design Studies for a Stabilized Shipboard Crane,"* FCR Report No. F-6171 (May 1987).

The Franklin Research Center (FRC) has devised a means to stabilize suspended cargo in all six degrees of freedom, using six individually controlled cables in tension in a unique kinematic arrangement.

The objective of these design studies is to establish the technical and economic feasibility of the new, stabilized cargo-handling system. The main feature of the system is a multi-cabled crane that can generate stabilizing forces and torques in all six degrees of freedom. Appropriate inertial and distance sensors, coupled with high-performance cable drives, provide the means to control the multi-cabled crane automatically. The distance sensors are used to track the target container of lighter during the pickup and setdown modes of operation. The inertial sensors are used to prevent pendulation during transfer of the cargo from the seagoing cargo ship to the vicinity of the receiving lighter. The complete stabilized shipboard crane system is intended to permit safe and efficient LOTS operations in relatively high sea states.

120. Frick, H.E. and D.J. Mottran, *"Open Sea Transfer of Articles,"* British Aerospace Public Limited Company, US PATENT-4 854 800 (Aug 1989).

Abstract: An arrangement for effecting open sea transfer of articles to and from a vessel subject to movement in the pitch, roll, yaw, heave and sway senses includes a gantry having one end carried by the vessel, and a free end having a carrying device adapted for carrying an article, the gantry being articulated such that the carrying device can be substantially stabilized in space whereby it maintains a generally constant position or course in space irrespective of the motion

of the vessel.

121. Fulton, S.K., "*Marine Facilities,*" US PATENT-3 306 053 (Feb 1967).

Briefly describing the invention, provision is made for a plurality of interconnected floating docks which may be coupled to piles, to each other, or to a sea wall, in various configurations. The individual floating docks are fabricated of cast concrete, having therein expanded polystyrene beads or other cellular plastic material, the proportion of concrete to cellular material being such that the docks float, and the exterior of the docks being entirely made of concrete, which is virtually ageless in any type of water, which requires substantially no maintenance, and which has extremely long life under operating conditions.. Individual docks may be secured together and buffered from each other by means of rubber block elements which are held in compression by stainless steel cables extending between pairs of docks on a line extending through the blocks. the cables being under tension. The location and shape of the coupling or buffering element is such as to provide or permit only relative flexing of two adjacent docks about a fixed axis under the action of sea or waves, and no other relative motion. The material of which the coupling is fabricated is rubber, neoprene or the like tough resilient material. The coupling provides shock absorption and the location thereof provides a gangplank extending between docks, which is flush with the surfaces of the docks, enabling personnel readily to pass from dock to dock.

122. General Electric Company, *"Design and Development of a Counter-Balance Winchdown Motion Compensating Cargo-Handling System for Loading Lighters at Shipside, Technical Proposal,"* (Mar 1971).

123. Gibb. P.R. and P. Bartsch, "*Weight Type Motion Compensation System for a Riser Moored Tanker,*" NOVACORP International Consulting Ltd., US PATENT-4 567 842 (Feb 1986).

A system for mooring a ship-shape floating production system using a riser tensioned by a weight type motion compensation system. The riser is attached to the ship by a rocking beam that has a weight attached at one end of the beam to balance the vertical load component of the riser attached at the other end of the beam. A rocker arrangement is used whereby the beam support point moves to compensate for the inertial forces of the weight caused by the vertical accelerations of the tanker. Thus the high load fluctuations and hence poor riser fatigue life usually associated with weight type motion compensators is minimized. A gear arrangement is used to transmit horizontal loads. The overall arrangement provides a totally self-contained motion compensation and riser handling system that requires minimal ship modifications and is independent of significant self-induced wave loading.

124. Goldman, J.L., *"A Lighter - Ship Stabilizing System,"* Lash Systems, Inc., US PATENT-3 722 449 (Mar 1973).

The present disclosure is directed to a lighter ship stabilizing system for securing vertical stacks of lighter within cargo holds against tilting or rocking of the stack of lighters relative to the ship to effectively make the stack of lighters and the ship a single instrumentality which resists relative motion between lighters and ship incident to dynamical sea conditions such as pitch, roll, and yaw. This rigid interplay between lighter and ship is based upon the fact that the lighters may be nested or stacked within the hold so that as between lighters in a particular stack there is interlocking rigidity and the stack is made rigid with the ships hull by wedging the stack of lighters against the hull. This interlocking is attained by the use of wedge blocks secured to the hull and tapered wedges which are dropped between the stack of lighters at each lighter and rigid part of the ships hull.

125. Gooden, John and Jason Paul, "*Improved Coring from Floating Craft by Optimizing Heave Compensator Designs,*" Mar. Min., Vol. 8, No. 1, pp. 41-54 (1989).

Improvements to the design of heave compensators have heightened the role of ships in the market for coring at sea. The development of hard tie coring techniques off compensators has introduced smaller, lower cost vessels and enabled them to challenge the lightweight jack-up platforms in shallow near shore waters. Details of heave compensator design are analyzed, studying and comparing the performance of various systems with the latest developments in their technology. The choice of system can affect the motion characteristics of the vessels, particularly with smaller craft, and may preclude some of the more sensitive compensator designs. Methods of coring from various compensators are discussed with emphasis on the indirect hard tie methods developed by Seacore Ltd., describing their ability to improve core quality as well as widen the pool of suitable ships. (Author abstract) 4 Refs.

126. Goodyear Aerospace Corporation, *"Crane Power Requirements Study for Cargo Transfer in Rough Seas,"* Goodyear Aerospace Corporation Report GER 16226 (May 1975).

The power requirements for a crane off-loading a heavy container from a C4 cargo ship to a LCM-8 lighter in rough seas are calculated. In addition, the geometric interference between the crane and the moving cargo ships and lighters was investigated. The results are presented and various approaches to the design of the cranes are discussed.

127. Goodyear Aerospace Corporation, *"Demonstration of a Relative Motion Sensing System for Cargo Transfer,"* Goodyear Aerospace Corporation Report GER 16418 (Dec 1976).

A program is described in this report for the development and laboratory simulation test of a breadboard model relative motion sensor incorporating a solid-state digital pattern tracker, a TV camera, and a vertical reference. The objective was to demonstrate the feasibility and evaluate the performance of the sensor for measuring relative motion between a crane-mounted sensor and a lighter. The sensed relative motion, both translation and rotation, could be used as an input to the crane's control system for automatic container motion control when loading or for retrograde during high sea states.

128. Goodyear Aerospace Corporation, *"Development of Energy Spectrum Techniques for Relative Motion Crane Horsepower,"* Goodyear Aerospace Corporation Report GER 16252 (Sep 1975).

After linearizing the expression for the horsepower requirements of Relative Motion Compensating Cranes, traditional methods of energy spectrum analysis are applied to the development of a calculation routine for estimating the horsepower of such cranes. A sample problem is presented for a Rotary Boom Type Crane with Articulated Arm. A brief study is conducted of a promising approach to the problem of non-linearities.

129. Goodyear Aerospace Corporation, *"Relative Motion Compensation Study For Cargo Transfer In Rough Seas,"* Goodyear Aerospace Corporation Report GER 15872 (Feb 1973).

This study recommends a solution to the problem of the inability of existing cargo handling systems to off-load cargo during rough sea conditions in amphibious operations. An active crane system with relative motion sensing equipment that automatically causes the cargo to follow the deck of the lighter on which it is to be set. Motion compensation ability in transverse (surge and

sway) and vertical (heave) directions is provided.

Specifically, the system recommended consists of a main boom and a king post configuration capable of handling 70 tons at a reach of 72 feet. An articulated arm is attached at the base of the main crane capable of providing pendulation control and relative motion compensation capability in any transverse direction.

Vertical motion compensation is provided by power applied to the main crane winch. Capacity of the crane system when used in a motion compensation mode is 50,000 pounds. At the heart of the system is a motion sensing device which provides a signal to the control mechanism which in turn automatically drives the package to follow the deck of the lighter. A secondary passive system of bumpers is recommended as an answer to the problem when the installation of an active crane system is not possible.

130. Goodyear Aerospace Corporation, *"Relative Motion Compensation Sensing System Study For Cargo Transfer in Rough Seas,"* Goodyear Aerospace Corporation Report GER 16191 (Dec 1974).

The effort described herein comprises the second phase of a program to provide a crane having relative motion compensation for the transfer of cargo in rough seas.

The effort on this program was directed exclusively to the relative motion sensing system and included establishing preliminary requirements and generating concepts to satisfy the requests. A trade study was then conducted to establish the baseline sensing system. This baseline sensing system is described in detail.

A development plan was then generated for the baseline sensing system which at its completion will prove feasibility of the sensor system.

131. Graham, J.R. and R.C. Crooke, *"Deep Ocean Mining Ship,"* Global Exemplary Claims, US PATENT-3 919 958 (Nov 1975).

A ship with special features for mining the ocean floor while operating in water depths in excess of 18,000 feet. These include first, a very large well in the center of the ship, passing through, but enclosed by the hull. The well is closable across the bottom by movable gates. Second, a pipe-handling system for moving large diameter mining pipe sections between the storage hold in the hull and the rig floor in the derrick where they are joined to or disconnected from the existing pipe "string" from which the mining machine is supported. Third, the lift system which operates to raise or lower the pipe string on continuous feed basis. Lastly, the derrick, derrick pipe-handling equipment and entire lift system are motion compensated in roll, pitch and heave such that the derrick and suspended pipe string remain vertical with respect to the earth, isolated from the actual sea-induced motions of the ship. The entire motion compensated system is supported over the center well by a large structural A-Frame.

132. Gridley, H.D., *"Cargo Handling Apparatus,"* US PATENT-3 332 716 (Jul 1967).

This present invention relates generally to the art of cargo handling, and more particularly to a new and novel apparatus for loading and unloading cargo from a ship by the normal shipboard hoisting lines forming part of the ship's gear.

It is a major object of the present invention to provide apparatus for loading and unloading ship that eliminates the need of manually aligning a pallet-receiving fork lift.

133. Gronningsaeter, Arne, *"The Behavior of Fishing Vessels,"* Canadian Fisherman (May 1966).

134. Gunderson, S.R. and L.C. Ruth, *"An Investigation of the Relative and Absolute Ship Motions of Ships Involved in the Offshore Discharge of Containership (OSDOC II) Sea Trials,"* NSRDC Report 515-H-01 (Mar 1973).

Full scale ship trials were conducted one mile off the coast at Fort Story, Virginia, to both evaluate and determine the feasibility of equipment, procedures and systems for the offshore discharge of containerships including the movement of containers to the shore and across the beach. This exercise was a joint Army-Navy operation. Motions of the containership, unloading vessels, and lighterage were measured. In addition, relative motions between the ships were measured. A Datawell Waverider buoy was used to measure wave height.

135. Hallanger, L.W. and R.L. Brackett, *"Development and Evaluation of a Motion Compensating Lift System for Deep Ocean Construction,"* NCEL Report R-829 (Dec 1975).

A system to raise and lower loads in the deep ocean while providing lift-line tension control and payload motion control was designed, fabricated, and tested. Design parameters included a maximum wet payload weight of 40,000 lbs at a maximum operating depth of 6,000 ft through sea state 4 conditions when the system is mounted on a Auxiliary Recovery Ship (ARS) type vessel. A load-handling system of this type allows soft landing of a payload on the seafloor. In addition, the reduction in the dynamic tensions in the lift line allows the use of smaller lines for a given payload weight, greater payload capacity for a specified line size, or a greater depth capability for a given line size. The concept selected for development, called a "boom bobber", incorporated a boom pivoted end and supported by a relatively soft passive fluid spring. This spring decouple the payload from the motion of the support platform. At-sea testing included, determination of system performance for two payloads of 12,000 and 40,000 lbs wet weight. Cable tensions and time correlated motions of the ship, lift system, and payload were recorded. Data obtained were sufficient to prove the promise of the basic concept, even through both at-sea series ended with specific component failures.

136. Hanke, A. M., *"Tensioned Highline System,"* Secretary of the Navy, US PATENT-3 713 548 (Jan 1973).

A highline transfer system for transferring loads between ships underway at sea having a highline winch and a ram tensioner to compensate for relative ship motion and a folded highline connected to a winch having three drums. The first and second drums of the winch are connected to spool opposite ends of the folded highline and the third drum is operably connected to the ram tensioner to drive the first and second drums in relatively like directions in response to relative ship motion. A power means is connected to selectively drive the first and second drums simultaneously in relatively opposite directions for positive control of the load with respect to the receiving ship for positive control of the load with respect to the supply ship.

137. Harrison, J.H.,M. H. Patel, and D. T Brown, *"Hydrodynamic Analysis of Marine Vehicles with Pneumatic Compliance,"* R. Inst. Nav. Archit. Suppl. Pap., Vol. 129, pp. 223-231 (Jul 1987).

This paper describes the development of coupled hydrodynamic analyses for marine vehicles having pneumatic compliance which is utilized in a system for suppressing the wave-induced motions of the vehicle. The pneumatic compliance arises through the use of open bottom tanks mounted on the vessel. These tanks pierce the water surface and trap volumes of air above their

internal water levels. For semi-submersibles, wave action on the tanks induces oscillating vertical forces which reduce the level of the total wave-induced heave force acting on the vessel. For monohulls, the pneumatic compliance reduces the wave-induced roll motions through changes in roll stiffness and damping. This paper describes the formulation and application of multi-degree of freedom hydrodynamic analyses required to account for the six rigid body vessel degrees of freedom as well as the additional modes of vibration and coupling due to the trapped air and water columns in the open bottom tanks. The analyses are applied to two vessels and predictions from theory are compared with model test data. (Author abstract) 14 Refs.

138. Haselton, F.R., *"The Sea Ratchet for Semi Heave Reduction,"* Hydrospace Challenge, Inc., in: Offshore Technology Conference Proceedings, OTC Paper 752, 283 (1975).

The Sea Ratchet is a device which will substantially reduce wave induced motions as well as increase deck loading flexibility.

Slung deeply beneath existing semis using chains, the ratchet action results from its upward only damping action entraining a hundred thousand tons of apparent mass. Filmed scale model tests are shown.

139. Heese, William E. and John R. Sutton, *"Method And Apparatus For Connecting A Tug With A Barge,"* US PATENT-3 949 699 (Apr 1976).

A method of and apparatus for connecting two vessels, such as a tugboat and a barge, to form a composite vessel, are disclosed. The method uses hydraulically powered apparatus completely controlled from one of the vessels to extend a shaft from one vessel toward the other vessel which has apparatus to capture the extended shaft. The method accommodates substantial misalignment between the vessels being connected by permitting lateral adjustment during connection. The apparatus for effecting the connection includes an active member carried by one of the vessels and a passive member carried by the other of the vessels. The active member is hydraulically actuated, includes a longitudinally reciprocable shaft which is actuated by a powered toggle linkage, and includes a release mechanism. The passive member is carried by the other of the vessels and automatically engages the shaft of the active member. The toggle linkage establishes a latching mechanism which does not require separate locking members and which does not fail in the event of pressure loss or hydraulic fluid leakage.

140. Henderson, Homer I., *"Stabilizer For Marine Vessels,"* US PATENT-3 537 412 (Nov 1970).

A stabilizer for a marine vessel having pipes termed "buoy pipes," of relatively large diameter secured on each side and each end of the vessel; the pipes projecting downwardly into the water for a distance that is many times the draft of the vessel and the lower end of said pipes being open while the upper end is closed. Air is pumped into the buoy pipes to displace water therefrom. The resultant pressure of the air corresponds to the head of water displaced. The air pressure within the buoy pipe generates an upward force on the closed top of the opened buoy pipe, which force is a product of the pressure within the buoy pipe and the buoy pipe's internal area. A sufficient number of pipes, of sufficient area, and depth of submersion, are used so as in actually pneumatically jack the vessel above the water's surface a sufficient distance as to be above the crest of surface water waves. Each cubic foot of water displaced by air gives a lift equivalent to the weight of 1 cubic foot of water.

141. Hillberg, T., *"Control of Dynamic Bodies in an Open Seaway,"* Delta Marine, presented at Gastech '84 (Nov 1984).

A valid solution to the potentially "fatal flaw" in LNG/LPG offshore terminalling (mooring two or more dynamic bodies in an open seaway, and safe and effective transfer of cryogenic fluids) has been demonstrated. The Controlled Mooring Concept utilizing the CML and off-the-shelf hardware offers an effective mooring and cargo transfer system for liquefied gas and other hazardous and non-hazardous materials.

142. Hoffman, D. and V.K. Fitzgerald, *"Systems Approach to Offshore Crane Ship Operations,"* presented at SNAME Annual Meeting, New York, NY (1978).

143. Hooper, D.W., *"Heave Compensator,"* Global Marine Inc., US PATENT-3 905 580 (Sep 1975).

A heave compensator for a floating vessel maintains a substantially constant load on a coring or drilling tool at the bottom of a drill string supported by the vessel. The heave compensator includes a displacement compensating cylinder having an adjustable volume of hydraulic fluid presented to a piston in the cylinder and supporting the upper end of the drill string. The volume displacement of fluid in the cylinder varies in response to the heave of the vessel to maintain the drill string in a substantially fixed position independent of the heave of the vessel; this, in turn, provides a substantially constant load on the tool. The displacement compensating cylinder is hydraulically linked to one side of a servo ram in a hydraulic accumulator for accommodating fluid from the displacement compensating cylinder. The opposite servo side of the servo ram is initially buffered by a passive airbank when the load on the tool is within narrow plus or minus limits. When the load exceeds these limits, a hydraulic servo system linked to the servo ram actively assists the passive airbank in compensating for the excessive load excursion. The servo system includes means for sensing predetermined excursions in the load or the tool, and a control valve which either presents hydraulic fluid from a pump to the servo ram, or vents hydraulic fluid from the ram in response to operation of the sensing means when the sensed load reaches it predetermined limits.

144. Huang, T. S., *"Random Motions Of An Offloading Ramp - A Parametric Study,"* Technical Memorandum for Naval Facilities Engineering Command (Feb 1985).

A numerical model was developed to simulate the random motion of an offloading ramp deployed between two floating structures in open seas. The time domain solution describes the ramp motion created by a set of prescribed motions of the supporting structures. Parametric studies were conducted to investigate the effect of end constraints (i.e., the spring constants and the friction coefficients) at the joints between the ramp and the supporting structures. The effects of loading configurations and wave headings were also investigated. The results are presented in graphic form as well as discussed in the body of the report.

145. Huang, T.S., *"Causeway Ferry Motion in Irregular Seaways,"* NCEL Report TN N-1715 (Nov 1984).

The causeway ferry is used to transport offloaded cargo from a ship via a causeway platform facility to the shore. The operation of the causeway ferry depends on its performance in irregular seaways. This effort evaluated and modified an analytical model for predicting causeway ferry motion responses. Model tests of a four-section causeway ferry were conducted to verify the applicability of the theory. The results suggest that the theory predicts motion response functions

with acceptable accuracy. The practical application of the theory shows a 90 percent probability of maintaining a dry deck while operating in a sea state 3. Further investigations show a 98 percent probability of a dry deck while operating in a sea state 2.

146. Huse, Erling and Rolf Borresen, *"Heave, Pitch, and Roll Damping of Platforms and Ships Due to Positioning Thrusters,"* Norwegian Hydrodynamic Laboratories, in: Offshore Technology Conference Proceedings, OTC
Paper 834,605 (1983).

Semi-submersible platforms and large volume floating structures are usually designed in such a way that their heave, pitch, and roll motions due to first order wave forces shall be minimum. The most important component in the motions of such platforms is in many cases the resonant motions induced by second order wave forces. Since the motions occur at resonance, and since the relative damping is often very small, the resulting motion amplitude is very sensitive to the hydrodynamic damping of the structure. The present paper demonstrates that the application of positioning thrusters may introduce damping of such structures. This means that it may be necessary to include the effect of positioning thrusters when predicting or evaluating the motion characteristics of semi-submersibles and other dynamically positioned structures. The effect can also be used when particularly critical operations are to be carried out, e.g. crane operations, transfer of personnel, etc.

147. Hydronautics, Inc., *"Predictions of Wave Induced Motions of TCDF Crane Barge,"* Hydronautics Report 7921-1 (May 1979).

148. Hydronautics, Inc., *"Rough Water Mating of Roll-On/Roll-Off Ships with Beach Discharge Lighters,"* Technical Report TR-636-1 (Jul 1967).

The mating of two large ships in rough seas for the purpose of transferring cargo from one to the other is, as one could expect, an exceptionally difficult maneuver. The basic purpose of developing the beach discharge lighter, USAV LT COL JOHN V.D. PAGE and the roll-on/roll-off ship USNS COMET was to provide such a mating capability. In this way, it was intended to be able to unload the COMET and transfer the material to an unimproved beach. Experience has shown, however, that the mating maneuver can not only be difficult but can be dangerous as well. As a result of this study, it was described that mating could not occur if the relative motion between the two vessels is greater than four feet. Since this condition occurs at relatively low sea states (upper sea state 2) the usefulness of these ships for mating was severely compromised.

149. IIT Research Institute, *"Development of Rating and Dynamic Simulation Procedures for Shipboard Mobile Cranes, Final Technical Report,"* (Mar 1977).

150. IIT Research Institute, *"Dynamic Crane Derating Procedure Assessment IITRI Project J6372,"* (Jun 1976).

This report presents the results of a review and assessment by IITRI of a previously developed procedure for the determination of load ratings for cranes subjected to the dynamic motions experienced by a moored platform in the open sea.

151. Ishitani, H. and Y. Takeuchi, Journal of the Japan Society for Simulation Technology, Vol. 6, No. 3, pp.

169-77 (Nov 1987).

A simple attitude control system to stabilize cargo carriers is proposed, with which loaded cargoes are stabilized so that they do not slip or fall down while the vehicle is accelerated or turning. The attitude of the carrier is adjusted by moving the suspension actively according to the acceleration and attitude of the cargo with proper sensing devices. The control system and algorithm are presented and evaluated by simulation study. Some results of simulation runs when the carrier moves with unstable cargo on its platform turning along a predetermined curved path are shown. From these results, it is assured that the proposed system can transport free cargo safely within appropriate acceleration provided that approximate dimension (size and weight) of the cargo is estimated in advance and control parameters are tuned for that condition.

152. J.J. Henry Company, *"Analysis of Containership Offloading at Advanced Operations Area,"* J. J. Henry Company (Aug 1975).

A trade-off analysis of Containership Offloading Concepts at an Advanced Operations Area (AOA) was performed. This analysis addressed primarily the Marine Corps resupply requirement and evaluated in detail only total system cost of the alternate offloading concepts under the most ideal circumstances where the container retrograde, ship vulnerability, RM&A problems, environmental effect en route and at the AOA, and lighterage/beach facility limitations were not considered. This report analyzes the effects of the other factors (except ship vulnerability and RM&A) on the alternate system.

153. Johnson, Frank R., Jr., *"Procedures for Determining Load Ratings for Truck Cranes Supported on a Floating Platform Moored in the Open Sea,"* CEL Report M-51-76-1 (Feb 1976).

154. Johnson, Kenneth V., *"Theoretical Overload Factor Effect of Sea State on Marine Cranes,"* Bucyrus-Erie Company, in: Offshore Technology Conference, OTC Paper 762, 584 (1976).

155. Kaplan, P. et al, *"An Investigation of the Relative Motions of ACV Landing Craft and Large Amphibious Assault Ships,"* Oceanic, Inc. (Feb 1972).

A mathematical analysis is used to determine the relative motions between an ACV landing craft and different assault ships under operating modes corresponding to well entry and alongside conditions associated with cargo transfer. The technique used is based on linear equations of motion, with probabilities of carrying out the operational tasks being determined from knowledge of statistical motion response data obtained via spectral analysis methods. The results provide guidance as to best operating speed of the assault ship and of the ACV; preferred heading relative to the waves; best orientation and position of the ACV relative to the assault ship; and limiting sea state conditions for safe and/or best operations to occur. Particular areas of importance for which little information ia available, and which have a significant influence on the results, are identified and recommended for further investigation.

156. Kaplan P. and R.R. Putz, *"The Motions of a Moored Construction Type Barge in Irregular Waves and Their Influence on Construction Operation,"* NCEL Report CR-62-8 (Aug 1962).

Results and methods are given for a theoretical study of the behavior of a moored construction-type barge and that of a load, lowered by means of a line from the barge, in irregular seas in deep

water. Load-lowering through the hull as well as by means of a boom having variable azimuth angle is considered. Equations of motion of the system for sinusoidal waves are formulated for 6 degrees of freedom, including both hydrostatic and hydrodynamic effects. Sinusoidal solutions of these equations are obtained for each of the 6 barge motions (surging, heaving, pitching, swaying, rolling, and yawing), as well as for the components of the load displacement vector, the vertical component of the load acceleration and the added dynamic tension in the lowering line.

157. Karsan, D.I., Z. Demirbilk, *"Method and Apparatus to Stabilize an Offshore Platform,"* Conoco Inc., US PATENT-4 938 630 (Jul 1990).

Method and apparatus to stabilize a columnar platform for deep water offshore applications. An added mass stabilizer system is utilized to control first order heave, pitch, roll, surge and sway motions of the floating platform . The stabilizer is suspended beneath the platform by a set of tendons a sufficient distance to (1) enter a quiescent zone beneath the action of waves and currents, (2) provide a sufficient long movement arm to resist pitch and roll torquing, and (3) incorporate sufficient flexibility into the suspension system to avoid shock loads, the stabilizer is sized to (A) provide sufficient submerged weight to maintain the tendons in constant tension and, (B) create adequate added mass (actual stabilizer weight plus mass of water moved by the stabilizer) to provide the desired control of first order motions. A secondary mooring system such as a spring-buoy mooring or dynamic positioning system can be provided to control drift produced by higher order motions and first order yaw. Primary example claim: A column-stabilize floating platform for utilization in deep water, offshore hydrocarbon exploration and production, above a selected portion of a seafloor, said platform comprising: A floating platform ha ing at least one column which is at least partially hollow to provide positive buoyancy, said column supporting at least one above-surface deck; A stabilizer connected to and suspended a substantial distance beneath said floating platform by a plurality of suspension tendons, said stabilizer having (A) sufficient submerged weight to maintain said suspension tendons in tension and (B) a sufficient added mass, produced by said submerged weight plus resistance to motion of a portion of the water surrounding said stabilizer, to satisfactorily control first order wave-induced heave, pitch, roll, surge, and sway motions of said floating platform without the need for anchoring said platform to said seafloor.

158. Keefer, B.G., *"Development of Motion Compensating Cranes for Rough Sea Operations,"* Synopsis for Oceanology International, B. C. Research (1975).

159. Kerr, Andrew Guy and Robert Arthur Morley, *"Load Transfer,"* US PATENT-4 118 012 (Oct 1978).

Control of vertical motion of a suspended crane hook assembly to accommodate vertical motion between a station carrying the crane and a station carrying a load is achieved by a transducer on the hook assembly and a control cord depending onto the load station. Tension above a set value in the cord produced by a crew member on the station causes the hook assembly to descend and below the set value causes it to rise. Movement of the stations causes a continuous adjustment of tension and the hook assembly follows the motion, extra tension being applied to guide the hook assembly down to the load and vice versa.

160. Kerr, Andrew Guy and Robert Arthur Morley, *"Indication Means For Indicating Suitable Conditions For The Transfer Of Loads Between Two Stations Movable Relative To Each Other In A Vertical Plane,"* US PATENT-4 121 293 (Oct 1978).

For use with apparatus for transferring a load between two stations movable relative to each other in a vertical plane by means of a crane carried by one of the two stations having a hook assembly for attachment to the load on the other station for lifting the load, a lift-off indicator measures either the relative velocity or relative vertical accelerations of the two stations and from signals representing relative velocity of approach showing values between a maximum positive and a negative, and relative acceleration acting away from the direction of approach indicates conditions suitable for initiating lifting.

161. Khan, F.A., *"Crane Motion Compensator,"* NL Industries, Inc., US PATENT-4 268 013 (May 1981).

A method and apparatus are disclosed for displacing a crane lift hook and hook cable to follow the relative vertical motion between a crane and a loading deck such as occurs between floating vessels and a fixed crane. In the method, the hook cable is paid out or reeled in maintain the hook at a substantially constant distance from tne deck in order to facilitate loading or unloading of cargo from the hook. The apparatus for achieving the method includes a vertically displaceable sheave over which the lift cable is reeled, a power ram to displace the sheave, and motive means operating the power ram. Preferably, the power ram is subjected to a constant upward pneumatic force to provide at least a portion of the force for displacing the moveable sheave upwardly to reel in the cable, such as in response to an upward heave of the deck relative to the crane. Variable displacement hydraulic pumps provide an additional hydraulic upward force to the power ram or alternatively provide a downward hydraulic force to displace the sheave down and pay out the cable, such as when the deck moves away from the crane.

162. Kim, C.H., *"Description of the Computer Program for Coupled Side by Side Ship Motion,"* Stevens Institute of Technology (Jul 1985).

The computer program relative motion can calculate the vertical and lateral relative motions between the tip of a crane of a ship and an unloading deck area of a lighter adjacent ship in oblique seas.

163. Kim, C.H., *"Hydrodynamic Interaction Between Two Cylindrical Bodies Floating in Beam Seas,"* Stevens Institute of Technology, STI-DE-72-10 (Oct 1972).

164. Kim, C.H. and M.C. Fang, *"Vertical Relative Motion Between Adjacent Platforms in Oblique Waves,"* Journal of Energy Resources Technology, Vol. 107, pp. 455-460 (Dec 1985).

The paper presents a strip theory and its correlation with experiment and analysis on the relative motions of two ships. The ships are in close proximity and in parallel position in oblique waves. The two-dimensional procedure takes account of the hydrodynamic interaction between two cylindrical bodies. It was found that the strip method is a useful technique to predict the hydrodynamically coupled motions of two ships.

165. Kirstein, Herwig, *"Active Heave Compensation Systems on Board of Vessels and Offshore Rigs,"* Marine Technology, pp. 59-61 (May 1986).

Active heave compensation systems are being installed in increasing numbers on ships and offshore platforms. In order to avoid installing excess power to cope with high peak requirements, a new hydraulic system has been developed by which energy is recovered during

pay-out of the load. Systems with power matching control as described have a high degree of efficiency and therefore represent a step towards the future.

166. Kodan, N., *"The Motions of Adjacent Floating Structures in Oblique Waves,"* paper presented at ASME Third International Offshore Mechanics and Arctic Engineering Symposium, New Orleans, LA (Feb 1984).

167. Koelbel, Joseph G. Jr., Nathan R. Fuller, Jr., and Donald W. Handley, *"Paravane Roll Stabilization,"* 4th Ship Technology and Research Symposium and Proceedings, held in Conjunction with the SNAME Spring Meeting, Houston, TX Apr. 25-28, 1979, pp. 313-336 (Apr 1979).

The United States Navy is developing new vessels which will spend a large percentage of their time at low or zero speed and ship stabilization is required to permit the crew to function effectively. Paravane stabilizers are an inexpensive and effective method for low speed ship stabilization. The first use of the methodology to design an experimental rig for a 170 ton vessel is given.

168. Koman, B., *"Open-Sea Terminal in Hostile Environment,"* in Offshore Technology Conference Proceedings, OTC Paper 5347 (1986).

A shiploading terminal near Punta Arenas, the southernmost city of the world (53°-10'S, 70°-54'W) is described Strong winds, choppy seas, frequent gales, rain and snow make it difficult to load ships at an offshore berth in this area. Detailed site investigations, including a wind recording program, supplied sufficient information for the analysis of operating conditions. The weather pattern of the entire region, including the predictability of gales, was utilized in the analysis. The results showed that a bulk loading terminal at this location is feasible, provided that the design takes into consideration the specific problems of the site. The final layout shows a terminal that can be approached from several different directions, depending on the direction of the wind. The mooring system is arranged to allow alternative ways of attaching and casting off mooring lines and executing docking and departing maneuvers.

The berth is supported on piles and contains the minimum of structures, relying on a slewing shiploader to reach the ship in any position, with only limited fore and aft shifting of the vessel for loading the extreme hatches.

Results of wind recording, statistical analysis of wind and wave data, operating criteria and the results of berth availability analysis are included in the paper.

169. Kramer, D.J., *"Dock Connector and Stabilizer,"* US PATENT-4 543 903 (Oct 1985).

Disclosed is a dock connector for connecting two adjacent floating docks. The dock connectors are designed to accommodate substantial lateral, vertical and end-to-end relative motion between the docks. The dock connector includes mounting plates which are securely fastened to each dock segment and a spring which spans between and connects the two mounting plates. Spring connection means are provided to securely attach the ends of the spring to the mounting plates. Deflection limiters attached to the mounting plates help to support the spring and to prevent it from becoming sprung by over-deflection.

170. Kraus, T.W., *"Automatic Cargo Transfer at Sea Using a Crane,"* C. S. Draper Laboratory Report No.

T-713 (May 1980).

171. Kray, Casimir J., *"Safety of Ships and Structures During Berthing and Mooring,"* Marine Technology Society Journal, Vol. 16, No. 1, pp. 29-38 (1982).

This report discussed berthing problems from the viewpoint of waterfront structure safety and reviews the available approaches to a determination of hydrodynamic mass. Recommendations are presented to decrease the degree and frequency of incidents of damage to fenders, ships, berthing structures, communication appurtenances, towers, loading implements and arms or other equipment.

172. Kuperstein, D.W., *"Shipboard Craft and Cargo Handling Advanced Concepts, Final Report,"* Hunters Point Naval Shipyard Report TN-20-70 (Nov 1971).

This report contains proposals for future ships, craft, and equipment to augment or supersede the present cargo handling capabilities of the amphibious fleet. The approach has been to identify the major problems in amphibious cargo handling, to develop general solutions, and considering the present state of the art, to propose hardware or systems as specific solutions. Some recommendations are: LASH Type ships should carry preloaded landing craft to amphibious sites; containers may be most easily and economically transferred to the beach by means of flat, unpowered barges and unloaded by rough terrain straddle-lift trucks; roll-on/roll-off cargo handling can provide the most rapid response to needs ashore. In most cases, the technology and equipment necessary to speed cargo handling exists and only needs to be further developed for application to the amphibious fleet.

173. Kwok, Lloyd, *"Model Study of Bottom Founded and Moored Semi-Submersible Loading/Offloading Terminal (Vol. I and II),"* Arctec Offshore Corporation MA-RD-840-88005 (May 1987).

In January and February of 1987 a 1:48 scale model study of a mobile offshore drilling unit (MODU) as a cargo handling in-site port facility was conducted by Arctec Offshore Corporation. In this test program, the MODU considered was a semi-submersible of the GLOMAR Arctic Class. Two configurations were investigated. A bottom founded semi-submersible deployed as a container loading and offloading terminal was studied in the first configuration. In the second configuration two mooring systems, each with eight mooring lines, were considered for a floating semi-submersible. In this case the semi-submersible was used as a grain handling facility.

Conditions under sea states 1, 3 and 5 were investigated when either the container or grain vessel was berthed alongside the semi-submersible. Sea state 7 was used to study the behavior of the semi-submersible alone in storm conditions. Modified Pierson-Moskowitz spectra were used to represent different sea states. Measurements were recorded on magnetic tape and oscillographic charts. High quality surface video recordings, as well as still photography also documented the tests. This report describes the models, test setup, test results and feasibility of the concept.

174. Lakiza, Rostislav I., Petr Ivanovich Soloviev, Vasily Maximovich Dukov, and Grigory Rakhmielevich Baron, *"Crane Device for Preventing Collision of Load with Seacraft In Rough Weather,"* US PATENT-3 662 991 (May 1972).

A device mounted on a crane particularly a floating crane for preventing collision of a load with a seacraft being loaded in rough weather in which one end of a follow-up rope is secured to the

seacraft and the rope is reeved around blocks mounted on the boom with the other end being connected to a winch drum for changing the length of the rope to suit the changing distance between the crane and the seacraft. A load supporting rope is reeved around other blocks on the boom and blocks on a crosspiece connected with a mechanism for simultaneously tensioning of both ropes to compensate for changes in distance between the crane and seacraft. Such mechanism includes a two-arm lever mounted in the frame with one arm being connected to the crosspiece and the other arm articulated to a power cylinder-piston unit on the crane serving to turn the lever with a force required to prevent collision of the load with the seacraft.

175. Lange, J.F.H., "*Lifting Device,*" US PATENT-1 999 936 (Apr 1935).

This invention relates to improvements in lifting devices or cranes intended for lifting floating loads, such as hydro-aeroplane, from or launching such loads in, a rough sea which imparts to the load an irregular reciprocatory motion relative to the lifting device.

It is an object of the invention to provide means eliminating sudden jerks which are liable to be exerted by the agitated load on the crane when the lifting rope is suddenly tautened and to injure the load and the lifting device.

Another object is to provide means which will lift the floating load smoothly from the crests of the waves with a gradually accelerated speed; to provide means which will facilitate the job of securing the hook to floating load, for instance the hydro-aeroplane, and to provide a semi-automatic controlling equipment which facilitates the operation.

176. Larralde, E. and G. Robinson, "*Method and Apparatus for the Control of a Weight Suspended From a Floating Vessel,*" Vetco Offshore Industry, Inc., US PATENT-3 871 622 (Mar 1975).

This invention concerns the control of the suspended weight supported from a piston of a pneumatic hydraulic system on a vessel subject to wave and tidal action and particular any vessel employed in connection with submarine drilling operation. The particular improvement concerns their modulation of the pressure in a portion only of the system to compensate for changes in pressure in another portion of the system so as to maintain the total force on the piston substantially constant during each portion of the cycle action of the heave. This may be accomplished by supporting the load from a piston system supported by two cylindrical elements and independently modulating the pressure in one of them to compensate for variations in pressure in another of the cylinder elements.

177. Lawler, R.A., "*Topping Off in the Delaware Bay,*" Bulk System International (1985).

The Delaware River Port Authority has recently undertaken a major study into the establishment of and advanced bulk transfer system for the Delaware Bay. Presented in this report is a concept for a floating dry bulk cargo transfer terminal of operation in the Delaware Bay Anchorage. The proposal system is a floating platform (Seatrailer) on which is mounted two Siwertell cargo transfer systems. The transfer system is completely enclosed to protect the bay from water and air pollution. Transfer operation can be either "top-off" or "lightening" and can handle a broad range of commodities.

178. Layne, Douglas E., "*The Interaction of Two Vessels in Close Proximity,*" DTRC SPD-741-01 (Dec 1976).

Interaction effects examined in the NAVSHIPs sponsored study concerned the relative heading and rudder angles required when one ship is approaching, running alongside, and pulling away from another ship. These effects are obtainable by measuring forces and moments during captive model investigations. More specifically, the study concerned tow restrained models, one of which was positioned statically relative to the other. One model represented an aircraft carrier of the CVA-58 Class and the other, a fast combat support ship of the AOE-1 Class. The principal objective was to assess the interaction between these ships at various speeds and separations and thus determine the corresponding rudder and drift angles required to provide neutral forces and moments. Determination of drift angles has been neglected in earlier experimental work. It was included here because even though these values are thought to be relatively small, they could alter the amount of angle required of the rudder.

179. Leendertse, J.J., *"Analysis of Critical Motions of a Floating Platform,"* NCEL Report R-187 (Aug 1962).

Theoretical calculations and experimental measurements were made to determine the response to heave in the significant frequency range of 3 to 4 sec of the CUSS 1, an ocean-bottom drilling barge to be used in experimental trials prior to project Mohole. Roll was measured also.

Approximately 20 min of pertinent barge motion measurements were made during two cruises while the barge drifted in the Santa Barbara (California) channel. No measurements of water-level variation (sea state) were made.

It was found that in seas in the channel, estimated as from 2 to 3 ft in height and with significant periods of 3 to 5 sec as generated by winds of about 20 knots, the roll of the barge did not exceed three degrees and that its average heave at periods of 3 to 4 sec was about 1/4 in. The spectral density of the heave at a period of 3.4 sec was about 1/8 sq in/rad/sec.

180. Lembeck, H.G., *"Transportable Floating Bulk Grain Unloading Port Facility: Feasibility Research Report,"* Lembeck Associates, Inc. (Aug 1989).

The movement of grain is a major activity of the U.S. flag ocean transportation system. Efficient handling of grain at the foreign destination ports is of importance to the cost of ocean freight and therefore directly impacts the U.S. shipping industry as well as the U.S. Government, the farming industry, and other commercial interests. Offloading facilities at the destination ports are often inadequate or inefficient. Shallow draft berths, long vessel waiting times, and inefficient off-loading operations all have adverse effects on the cost of ocean freight. The development of a floating bulk grain unloading facility which would be readily transportable by LASH barges aboard a mother vessel is a solution to the problem and is both technically and financially feasible. Such a facility would: (1) provide rapid relief to temporary port congestion; (2) facilitate response in emergencies; (3) serve relatively undeveloped ports and river systems; (4) serve several ports at widely separated locations through movement of the unloading equipment with the cargo itself and (5) facilitate offshore lightening at shallow water locations.

181. Lichty, D.W. and L.J. Proebstle, *"Cargo Transfer System,"* Goodyear IR&D Project No. 1505-75S1 (Dec 1975).

182. Liu, F. C. and R. Sea, *"At-Sea Evaluation of a Ram Tensioner for Ocean Development and Recovery,"* ASME J. Engery Resour. Technol., Vol. 24, No. 2, pp. 241-246 (Sep 1982).

The results of three at-sea evaluations of the ram tensioner as ship motion compensation equipment have yielded positive data. Specifically, the sea tests have shown that snap loads were a realistic problem in deployment and recovery of flooded metal objects (such as aircraft of boats). Most importantly, the sea tests demonstrated that a standard Navy ram tensioner model THR1000A80 could effectively prevent snap loads in a lift system when used with a conventional winch. Snap loads could be prevented with payload weights ranging from 2400lb to 15,500lb with equal effectiveness. Although the tested sea condition was limited to a sea state of three, based on the measured tension data, the ram tensioner is as effective in a low sea state as in higher sea states. The only limitation is the amount of line travel available for ship motion compensation. With a + OR - 40ft of maximum line travel, the ram tension is expected to prevent snap loads in much higher sea states. The use of the Navy ram tensioner as ship motion compensator is highly recommended. (from paper)

183. Liu, Francis C. and Robert C. Whaley, *"Lift System for Salvage Operations,"* Mil.Eng., Vol. 78, No. 509, pp. 467-469 (Aug 1986).

To prevent life line tension failures generated by large wave-induced ship motions, a Fly Away Deep Ocean Salvage System (FADOSS) was developed to recover large bulky objects, such as aircrafts, weighing up to 55 kips in water depths to 20,000 feet. The key component is a ram tensioner Ship Motion Compensator (SMC), which eliminates the possibility of snap loads by maintaining a minimum tension in the line. To facilitate air shipment, the system hardware is modular. The FADOSS consists of a traction winch, SMC, a Hydraulic Power Supply (HPS), a high-pressure Air Storage Unit (ASU), a high-pressured air compressor, and fairlead blocks.

184. Liu, F.C. and R.C. Asher, *"At-Sea Evaluation of Ship Motion Compensation Hoisting Devices,"* Naval Civil Engineering Laboratory, in: Offshore Technology Conference Proceedings, OTC Paper 834,556 (May 1983).

Two ship motion compensating devices were tested off the coast of Oahu, HI. One device was a traction winch that is capable of maintaining a steady line tension. The other was a ram tensioner. Tests were conducted in various sea states and water depths. Ship and test load motions and lift line tension were measured.

The results of the sea test showed that this motion compensating traction winch was not effective in eliminating snap loads. However, the amplitudes of the snap load were reduced by the partial compensation of the winch. The winch had high static friction, which caused a time lag in response to tension changes. The ram tensioner was effective in eliminating snap loads. The maximum tension change in the lift line was less that 30% of the static load.

185. Locki, John N., *"Floating Hoist,"* US PATENT-2 572 165 (Oct 1951).

This invention relates to floating hoists, and more particularly to floating hoists for diving apparatus.

Among the several objects of the invention may be noted the provision of a hoist for diving apparatus, for use on salvage vessels or the like, adapted to permit diving operations in rough and turbulent waters; the provision of a hoist of the class described which compensates for wave-induced motion of the vessel to permit diving operations under adverse weather conditions; the provision of a hoist of this class adapted both for shallow diving operations by a diver in a flexible diving suit and for deeper diving operations by a diver in a rigid-walled diving chamber or compartment; and the provision of a hoist such as described adapted to traverse a diving chamber

or compartment, even in rough seas, so that a diver therein may carry on sub-sea exploration or other operation over a considerable area from an anchored salvage vessel.

186. Longreich, Randy and R.K. Wong, *"Supply Vessel Stern Mooring - A Passive System,"* Offshore Technology Conference Proceedings, Dallas, TX, pp. 195-204 (May 1980).

A Passive Stern Mooring System has been developed to allow supply boats and auxiliary vessels to remain in position adjacent to rigs and platforms during periods of inclement weather in order to facilitate the transfer of materials and supplies. The paper described the mooring arrangement and system operation, provides data pertaining to the elastic characteristics of double braided nylon rope and defines the procedures used to design each mooring system.

187. Lub, Dirk J.C., *"Compensation Device For A Crane,"* US PATENT-4 126 298 (Nov 1978).

A ship-mounted crane is provided with a compensation device for ensuring that its load rope will suspend a load selectively stationary relative to the ship, or stationary relative to a load-receiving surface relative to which the ship moves. For this purpose, the cranes is provided with a second rope separate from the load rope, and main and auxiliary pneumatic springs movable independently of each other. The load rope is trained about the main pneumatic spring; while the second rope is trained about both pneumatic springs and is selectively connectable to the load-receiving surface.

188. Macrander, Karl, *"Device For Transloading Floating Containers,"* US PATENT-3 756 446 (Sep 1973).

A transloading device, especially for ships, in which the device includes a vertically moveable support frame engageable with a floating container from above while a floating body is provided for engaging the side of a container to be lifted. Vertical tracks on the ship at one side of the support frame have carriages engaging the support frame from beneath while tracks on the other side of the support frame and at a higher level than the first mentioned tracks have carriages that engage the support frame from above. The engagement of the carriages with the support frame prevents swinging movement thereof while it is being moved vertically.

189. Maggi, D., *"Boat Lifting And Launching Mechanism,"* US PATENT-1 398 702 (Nov 1921).

This invention relates to mechanism for lifting, launching and retaining boats, intended primarily for use on vessels.

The purpose of the invention is to lift and lower a boat by sheaves located upon a swinging davit and a sheave block connected with the boat, fitting the sheave block to turn about the end of the davit as the davit swings, and lifting or lowering by a continuous pull or slacking of the rope leading to the sheaves.

190. Mahone, W.C., P. Van Luipen, and C. Werenskiold, *"Installation of Heavy Subsea Components using Submerged Motion Compensator and Multi-Sheave Block,"* OTC '87 Proc. Nineteenth Annual Offshore Technology Conf., Vol. 4 (Apr 27-30, 1987).

The results are summarized for a study that considered installation of heavy subsea production

components on the sea floor. This conceptual study uses a new generation semi-submersible crane vessel in water depths of up to 800 meters. The installation method described utilizes a submersible sheave block with an underwater motion compensator. A computer model of the entire system, with and without an underwater motion compensator, was developed to predict the motion of each subsea component as it was landed in its location on the sea floor. The model includes all elements in the system and incorporates the heave and pitch motions of the crane vessel as well.

191. Marbury, F., *"Heave Damping Device for Ships,"* Litton Systems, Inc., US PATENT-3 896 755 (Jul 1975).

This invention relates to a ship heave stabilization apparatus having horizontally rotatable fins in selective, operable connection with a ship's hull. The fins preferably are balanced about the hull and may be deployed on more than one hull in a multi-hull ship.

192. Marriner, John E., *"Flexible Connection For Articulating Vessels,"* US PATENT-3 799 100 (Mar 1974).

A coupling apparatus interposed between two vessels to connect such vessels in an articulated manner. The vessels may be components of a barge train. The coupling apparatus permits the barges to be individually removed from such train. The apparatus includes one or more resilient posts removably interposed between the vessels. The resiliency of the posts permits the posts to flex and bend for accommodating simultaneous relative movement in roll, pitch, yaw, surge and heave between the vessels resulting from wave action.

193. Marsden, J., *"Apparatus for and Method of Loading Loose Granular Material from Barges into Ships,"* Halter Marine Services, Inc., US PATENT-4 106 637 (Aug 1978).

A floating transfer vessel provides exterior mooring for a ship adapted to receive loose granular cargo, and interior dry-docking for a plurality of barges loaded with loose granular material within the transfer vessel. All relative motion between automated digging and conveying apparatus mounted in the transfer vessel and barge confines or cargo spaces are eliminated, to permit substantial reduction of working tolerances therebetween without possibility of damage. The reduced tolerances leaves very little grain to clean up requiring no additional independent equipment.

194. Martin, John P., *"Roll Stabilization of Fishing Vessels,"* SNAME San Diego Section (Jan 1972).

A brief history of the stabilization of fishing vessels throughout the world will be presented herein. The general design approach used for a passive anti-roll tank will be described. The reduction of rolling motion will be presented in three ways-- as predicted from model basin results, as devised from a statistical analysis of sea trial results and as a cumulative count of raw sea trial data. A brief discussion of economic and technical advantages and disadvantages will also be presented. Although all types of fishing vessels will be included, special attention will be paid to the large tuna seiners presently under construction at many shipyards on the Western Seaboard.

195. Martinussen, Svein, Leiv Roaldsnes, and Harold Roed, *"Method And Apparatus For Transferring Cargo Between An Ocean-Located Unit And A Vessel,"* US PATENT-4 166 545 (Sep 1979).

Method and apparatus for transferring cargo between an ocean-located unit and a vessel by way of a loading crane or derrick with associated winch and especially at sea under conditions of heavy wave movement. A cargo-supporting hook is subjected during loading and unloading to a controlled wave movement relative to the loading crane or derrick which corresponds to the relative movement between the ocean-located unit and the vessel and is in step with this relative movement.

196. Mathews, Sydney T. and Leopold I. Kawerninski, "*Marine Coupling*," US PATENT-3 353 512 (Nov 1967).

A device for interconnecting water-borne vessels so that one of the vessels can tow or push the other vessel. A single rigid structural member extends between the vessels, and is connected to one of the vessels by a universal joint, whereby controlled relative heave, pitch, roll, yaw and, in some cases, surge is permitted between the vessels.

197. Matsumoto, N., K. Suemitsu, M. Mzitsu, R. Fujimoto, and T. Kitani, "*Design Method for Characteristics of Dynamic Positioning System Equipped on Floating Offshore Structures*," Nippon Kokan Tech Rep Overseas, Vol. 44, pp. 103-111 (Aug 1985).

A method of prediction of positioning motion was proposed for the purpose of basic design of a dynamic positioning system (DPS) equipped on a floating offshore structure. Then, comparing the results of tests made on an actual semi-submersible drilling rig with the predicted results by the proposed method, the applicability of the method was verified in regard to the transfer characteristics of motion in the horizontal plane for periodic thruster operation. In addition, with the most severe environmental condition for design assumed on this type of rig, a thruster capacity offering the required positioning characteristics was determined and then the status and dynamic holding capability was calculated. It was thus confirmed that the proposed method is useful for basic design of DPS equipped on a floating offshore structure.

198. McClair, A., J. Slayer, D. Sanders, V. Santomartino, L. Baez, and H. Ruehsen, "*Stabilization of the Ship/Lighter Interface*," Designers and Planers, Inc. DPTR/LS/SSI-87/011 (Apr 1987).

The purpose of Phase I, Concept Definition, of the LOTS site/Sea State Interface Stabilization/(Buoyant Seawell) tasks were: demonstrate the feasibility of the concept; define the initial analytic bases for design and initiate the development of a Modular Manufacturing facility to produce buoyant cores, and assemble buoyant modules, at the LOTS Site. The feasibility of the concept was exhibited by Demonstration-of-Principle model tests performed using an empirically sized 1:12 scale model of the Buoyant Seawall in state 3 and 5 sea conditions. From analysis of wave probe data, it was determined that the model dissipated 40% and 15% of the wave energy in sea state 3 and 5 conditions respectively. These are hook results for an empirically sized model, and indicate that an engineered model will achieve better performance. It was concluded that by using greater section depth, and by operating the model at full immersion, significantly improved performance will be achievable.

199. McCool, John M., "*Winch Control System For Constant Load Depth*," US PATENT-3 596 070 (Jul 1971).

A winch control system for operating a winch stationed on a vessel, and for stabilizing a load, which is connected by a cable to a traction unit driven by a prime mover, at a constant height

above the sea floor irrespective of the vertical motion of the vessel due to wave action, thereby controlling the motion of the cable. A cable dynamics sensor, connectable to the cable between the traction unit and the load, generates output signals proportional (1) to its depth, and (2) to its velocity relative to the vessel. A tachometer connectable to the traction unit, produces a signal which is proportional to the velocity of the cable relative to the vessel. A depth-velocity summing circuit, connected to the cable dynamics sensor, is adapted to be connected to a sensor depth order signal, generated by a control console on the vessel, for summing the sensor depth and depth order signals, and is connected to the cable dynamics sensor and tachometer for summing the sensor velocity signal and the cable velocity signal. The two depth and two velocity signals, after being summed, produce an output control signal. A torque control, adapted to be connected from the output of the depth-velocity summing circuit to the prime mover, develops a torque signal proportional to the control signal, to cause the traction unit to null the control signal, thereby controlling the load position and velocity.

200. McKechnie, R.E. and P.A. Stricker, *"Analysis of Active-Passive Motion Compensation Systems for Marine Towing Applications,"* ASME paper, No. 75-WA/OCE-13 for Meeting Nov 30-Dec 4, 1975, pp. 7 (1975).

This paper discusses the design of active-passive motion compensation systems for marine towing applications, with particular emphasis on the analysis involved. With the ship's response to ocean waves as the input, equations were developed or presented to predict the response of the compensator as a function of the various mechanical and control parameters. It is shown how the compensator response can be used as an index of performance for design purposes, or how, if desired, the motion of the towed body can be predicted from the compensator response.

201. McWethy, P.J. and S.B. Nelson, ed., *"Handbook of Offshore Port Planning,"* Marine Technology Society (1974).

202. Meeker, Joseph F., Michael Keen, Larry E. Lee, and Roderick Charles LeJeune, *"Motion Compensation And/Or Weight Control System,"* US PATENT-3 912 227 (Oct 1975).

A motion compensation and/or weight control system mounted from a load-supporting assembly for supporting a load which is movable relative to the load-supporting assembly. The motion compensation and/or weight control system comprises an improved expansible and contractible mechanism mounted between the load-supporting assembly and its load. The improved expansible and contractible mechanism includes a passively operated piston and cylinder assembly for supporting the load and an actively operated piston and cylinder assembly for providing biasing forces. The system may be operated either in the pressure mode or in the position mode. When the system is operated in the position mode, hydraulic fluid is actively supplied to and withdrawn from the piston and cylinder assembly responsive to the velocity of the expansible and contractible mechanism and the velocity of the vertical movement of the floating structure relative to the earth.

203. Menz, D.D., *"Passive Shock Mitigation System with Sea Water Metering Shock Absorber,"* Dept. of the Navy, US PATENT-4 399 764 (Aug 1983).

204. Meyer, J.V., J.B. Wagner, P. Icasiano, *"Amphibious Assault Landing Craft Program. Over-the-Side Material Handling,"* Hunters Point Naval Shipyard, San Francisco, CA, Report No. HPNS-TR-1-72 (Feb 1973)

Relative motion between LKA-113 Class amphibious cargo ships and alongside moored LCM and

LCU landing craft has created and greatly restricted over-the-side cargo handling operations. The introduction of new generation landing craft such as the JEFF (A) and JEFF (B) air cushion vehicles into the amphibious fleet will further amplify existing alongside cargo handling problems by requiring greater over-the-side boom outreach and better load spotting capability resulting from wider and longer craft well deck dimensions. This report evaluates selected over-the-side cargo handling concepts proposed by other military activities and JEFF (A) and JEFF (B) contractors, and proposes new concepts which could possibly improve over-the-side cargo handling. Based upon this report's discussion, Qualitative Analysis merit chart, and the experience obtained from the use of telescoping and articulated hydraulic cranes on support ships which lift research and rescue submersibles from the sea, further study of the feasibility of such as cranes as part of the LKA-113 Class cargo handling system should be undertaken. Today's LKA-113 at-sea cargo handling could be improved considerably through the use of available 'off-the-shelf' hardware with a small increase in cost and material. To further improve load control and reduce load-to-craft deck impact loading and in view of today's emphasis upon reduced shipboard manning requirements, the use of portable crane controls and quick release hooks should be further investigated.

205. Meyer, S. and W. Zimmermann, "*Automatic Compensation of Load Swinging of Crab Drives,*" Siemens Review, Vol. 39, No.1, pp. 37-9 (Jan 1972).

Automation is gaining importance for loading and unloading equipment where the volume of goods to be handled is rapidly increasing. Such automation requires the location and movement of the goods handled to be known at any time during the operation. This, however, is not always the case on crane installations. Since the load is not rigidly connected with the crab, but is suspended from it by a swinging rope, relative motions will result so that neither the distance travelled by the load nor its instantaneous speed agree with the values measured at the point of suspension. Such deviations will naturally cause particular trouble on crane installations with high crab speeds and accelerations. Grabbing ship unloaders may be regarded as a typical example. The crab speeds of such plants may rise up to 270 m/min while the acceleration on rate is about 1 m/s^2.

206. Michael, F.Y. and D.B. Waller, "*Harsh-Environment Drillship Features New Hull Design,*" Ocean Ind., Vol. 21, No. 1, pp. 23-24 (Jan 1986).

A new drillship design providing extremely stable operations in harsh environments and water depths to 7500 ft has been developed by Waller Marine. Computer simulations and model tests indicate the motion characteristics of the new ship are almost equivalent to those of many semi-submersibles in operational sea states. The design is based on an innovative hull form concept, originally conceived and patented by F.Y. Michael, which combines a small water plane with heavy damping to reduce heave and roll motions. The hull shape of the new drillship can be likened to a traditional vessel with upper and lower sponsons attached along its entire length. This produces a vessel having high displacement with corresponding high dead weight and low water plane area. These are elements that naval architects have sought to obtain in conventional semi-submersible designs.

207. Michael, F.Y., "*Vessel Having Improved Wave Response Characteristics,*" Brown and Root, Inc., US PATENT-3 965 837 (Jun 1976).

A barge includes port and starboard sides in which longitudinal troughs are formed. Each trough is bound at its top by an outwardly direction undersurface of an upper wing section and bound at the bottom by an outwardly directed topsurface of a lower wing section. The topsurface of the

lower wing section is located for submersion during offshore operations to oppose heave and roll motions of the barge. An upper ballast system is provided in the upper wing sections to carry ballasting fluid above the center of the barge. A lower ballast system is provided in the lower wing sections to carry ballast fluid below the barge center. Operation of the upper and lower ballast systems enables a unique control of flotation characteristics to be provided. Namely, by ballasting the upper ballast tanks, the center of gravity is raised and the metacentric height is reduced. Deballasting of the upper ballast tanks causes a lowering of the center of gravity and an increase of the metacentric height. By ballasting the lower ballast tanks, the center of gravity is lowered and the metacentric height is increased. Deballasting of the lower ballast tank causes the center of gravity to be raised and the metacentric height to be reduced. Plates can be attached in spaced relation along the troughs to break the momentum of the waves and also to dampen rolling motions of the barge.

208. Mizell, Leonard, "*Marine Transfer Device*," US PATENT-3 426 71 719 (Feb 1969).

Marine transfer device includes ramp with inboard end pivotally mounted to a support and snuggling device mounted at outboard end of support. Snuggling device includes member rotatably mounted thereon and having a notch for receiving a marine device. Ramp may be raised or lowered by hydraulic ram, one end of which is secured to a support, the other end being secured to the ramp. Ramp also carries a hydraulic ram there within, one end being secured to ramp. Ramp also carries a hydraulic ram there within, one end being secured to ramp and the other being slideable along ramp. Cable is secured to slideable end of ram, disposed about snuggling device, and has free end for securement to marine vessel.

209. Montanari, Angelo, "*Buffer For Ships*," US PATENT-1 182 400 (May 1916).

The object of this invention is to provide simple and improved means for attachment to a collier which will enable it to approach a battleship or other vessel and to be tied thereto without danger of damaging either vessel, such means comprising a series of spring mattresses upon which are mounted outwardly-extending yielding buffers which carry buffer wheels which are designed to contact with the vessel to be coaled, each of such wheels having mounted in its periphery a series of rollers whose axes are transverse of the axis of the wheel, this arrangement permitting of relative anti-fractional movements between the vessels in vertical and horizontal lines.

210. "*Motion Suppression System for Semi-submersibles*," Mar. Engrs. Rev., p. 47 (Feb 1988).

A motion damping system for semi-submersibles is described. Open bottom tanks extending above and below the vessel's operating draught line can reduce heave motion in waves by over 50%. The advantages of the system are reviewed.

211. Motter, L., "*Extreme Values of Motion from RO/RO Discharge Facility Experiments and Trials*," DTNSRDC TM-15-86-157 (Jul 1987).

Several predictions, model experiments, and trials concerning the absolute and relative motion of various components of a Roll-On/Roll-Off (RO/RO) ship offshore off loading system have been reviewed. The results of each report have been compared to similar results of other reports. A table of estimated extreme motion values for the RO/RO ship and causeway platform motion in sea state 3 was determined from appropriate existing data. Recommendations are presented for

future work to improve motion predictions.

212. Naczkowski, B.R., *"Buffer System for Ships,"* North American Rockwell Corporation, US PATENT-3 585 958 (Jun 1971).

This invention relates to a buffer system that maintains adequate separation of two ships in an alongside mooring configuration; and will accommodate the relative motions of the two ships in a rough sea, to prevent the hulls from impacting. A plurality of inflated tires are biased in an outwardly moveable direction to maintain the desired spacing; and these yield in a controlled manner that is established by inflation pressure, snubber design, mechanical linkage, and the like.

213. Naval Electronics Laboratory, *"Profile for Open Ocean Crane Operators,"* (undated).

214. NCEL, *"Capabilities Expanded for Transferring Cargo from Ship to Shore,"* (Jun 1986).

215. NCEL, *"Estimates of Wave Induced Vertical Motion Between TCDF and COD Crane Booms and Receiving Lighterage,"* (Feb 27, 1975).

216. NCEL, *"OSDOC II Engineering Tests - Coronado, CA,"* NCEL Report No. TN-1258 (Dec 1972).

The Coronado engineering tests were conducted for purposes of evaluating the equipment capabilities and limitations of the NCEL concept. This concept evaluation included off loading 8'x8'x20' containers from a simulated non-self-sustaining containership and transporting the containers ship-to-shore in a roll-off mode via a pontoon causeway ferry shuttle, and across hardened beaches to a stabilized area. Available inventory equipment and techniques were used in these tests, such as a Navy floating YD-type crane, standard NL pontoons, Marine Corps truck/trailers, and Mo-Mat and On-Fast beach hardening. The tests were conducted in two phases: first, in the San Diego Harbor to familiarize the operators with the concept and procedures and second, in the open sea to evaluate the equipment concept. The results of the evaluation demonstrated the feasibility of the concept and the ability of the available inventory equipments to off load containers from ship-to-shore in wave/swell conditions in excess of original estimates for these equipments. Also apparent was the ability of the equipment operators to perform the concept functions with a minimum of special training and guidance beyond their normal training. The concept of a floating crane/causeway ferry shuttle is recommended for the joint service OSDOC II exercise.

217. NCEL, *"The Relative Motion Between Ships in Random Head Seas,"* Tech Note N-1183 (Sep 1971).

As part of the Navy's program to develop mobile port facilities, an analytical model has been developed which can be used to compute the relative motion between vessels in regular and random head seas. The model, based on strip theory, is suitable for analyzing all single hull, linearly moored slender vessels. Since symmetry of moorings (if present) is assumed throughout, the motion is restricted to heave, surge, and pitch. Deep-water added mass and damping coefficients are used in the equations of motion, and the resulting model predictions are considered valid provided that the draft-to-mean depth ratio does not greatly exceed 0.50. Typical results from the analysis are presented.

218. NCEL, *"Static and Dynamic Stability of Crane Platforms,"* (Mar 1975).

The Navy and Army are developing systems which are capable of unloading cargo from commercial vessels at advanced base sites. Unloading facilities would be established several days after an initial amphibious force landing and would be exposed to a nearshore wave, wind, and current environment. Equipment envisioned for the cargo unloading complex includes pontoon causeways, and various classes of lighterage for transporting cargo from the ship unloading site to the shore receiving area. The unloading of deck-stacked or cell-stored containers into the receiving lighterage is perhaps the most critical phase in the cargo transfer operation. Wave induced motion can cause large crane boom displacements regardless of whether the crane used to unload containerized cargo is located on the containership or is operating from a floating platform moored alongside. Excessive motion of crane booms results in load pendulation, lack of control in container placement aboard lighters, and unacceptable levels of container and lighter damage due to load impact. It is this critical problem of crane platform motion which is the subject of the present study.

219. NCEL, *"Summary of DT-II Tests for COTS Temporary Container Discharge Facility,"* NCEL Report No. TN-1668 (May 1983).

A series of controlled tests was conducted with a Manitowoc 4100 Series 3 ringer crane to obtain technical data in order to prepare specifications for future TCDF crane procurements. The purpose of this report is to abstract and reference all preliminary reports into one summary report covering the COTS-TCDF DT-II test program.

220. NCSC, *"Launch and Recovery Equipment for Shipborne Minehunting Sonar Systems (SMS),"* NCSC Report 07070-1-120-16069 (Dec 1, 1975).

221. NCSC, *"Operation and Maintenance Manual for Rider Block Tagline System (RBTS),"* (Nov 1980).

222. NCSC, *"Operations Handbook for Crane-On-Deck on Nonself-Sustaining Containerships,"* (Nov 1980).

Crane on Deck (COD) is an approach for providing nonself-sustaining containerships a method to off-load their own containers onto lighters in an open roadstead. It is designed to be readily available, rapidly installed, and adaptable to the majority of US Flag nonself-sustaining containerships.

The COD system consists of a crawler crane fitted with a 90-120 foot boom. The ship installation of the crane is facilitated by hatch cover bridging beams which permit the ship's structure to sustain the load of the crane and allow the crane to traverse to different ship holds. The system described uses commercial cranes which have limited capability to operate in other than calm seas. Equipment is now under development to provide the necessary pendulation control and vertical motion compensation to extend the ability of the COD so that it can operate in a sea state 3. Additional equipment required for COD operations include 20- and 40-foot container spreader bars and slings, and appropriate tie down and lashing gear for securing the crane and hatch cover bridging during transit and operational phases.

223. NCSC, *"Rider Block Tagline System COTS-TCDF Crane System Sea Tests S1-S3, S4B-S4D Note 4,"* (May 30, 1980).

The purpose of this series of tests was to demonstrate that the Crane/Rider Block Tagline System (RBTS) supports analytical predictions for safe operating load ranges when exposed to open harbor and mild sea conditions and that the RBTS, when properly installed, becomes an integral part of the crane.

224. NCSC, *"Ship Motion Trade-Off Analysis for the Container Off-Loading and Transfer System (COTS),"* Report No. TM 276-80 (Nov 1982).

Ship motion Response Amplitude Operators (RAO) were predicted for three containerships and three lighter vessels. Ship motions (surge, heave, sway, pitch, roll, and yaw) were also computed for three sea spectra: a Pierson-Moskowitz, a Bretschneider, and a Bretschneider pluss swell. Ship and crane motion data for head, quartering, and beam wave incidence angles are presented in tabular form with plots comparing barge motion RAOs given as a function of wave incidence angles. Significant displacements, velocities, and accelerations were calculated in each of the three coordinate directions for various rigid boom crane configurations. A sample procedure is presented for the Container Offloading and Transfer System (COTS) system design.

225. NCSL, *"Preparation of Input Data for COTS Ship Motion Study,"* NCSL Report 415 (Apr 4, 1977).

226. Nicoloff, Nicholoas and Eugene B. Osuch, *"Dual Loading and Stowage Apparatus,"* Dept. of the Navy, US PATENT-4 184 801 (Jan 1980).

227. MAR Inc., Contract Report. 1970-June 90, Contract NOO167-86-D-0119, Project Number RM 33062, Task Number RM 3306220 (Jan 1991).

A literature search was performed to review technical documentation in the area of relative motion. The information obtained from this search was developed into an annotated bibliography. The bibliographies are presented alphabetically, grouped in the following order: relative motion between two ships or craft, relative motion between a ship/craft and a fixed structure, related topics, and a bibliography of additional documents pertaining to the subject

228. Nojiri, Nobuhiro and Tsuneto Sasaki, *"Motion Characteristics of Crane Vessels in Lifting Operations,"* Ishikawajima-Harima Heavy Industries Co. Ltd., in: Offshore Technology Conference Proceedings, OTC Paper 834,603 (May 1983).

This paper deals with motion characteristics of crane vessels in lifting operations. Emphasis is laid here especially on the effect of coupled motion between a vessel and hook load. Linear equations for calculating motions of 8 degrees of freedom are derived. Results of calculations of motion responses in regular waves are shown to be in good agreement with those of experiments carried out on a scale model of a actual crane barge. Calculation of motion responses of a few types of crane vessels in irregular waves and a trial estimation of workability thereof are presented to show the influence of the coupled motion effect on performance of crane vessels in actual sea area.

229. Nolf, G.H., *"Boat-Docking Apparatus With Pressure-Responsive Grapple,"* US PATENT-3 177 839 (Apr 1965).

This invention relates to boat docking apparatus of the type disclosed in Patent No. 3,060,885, issued October 30, 1962, and has as its general object to provide a docking device of this general type, with improved features of construction and operation. Specifically, the invention contemplates the following objects:

(1) To provide a docking device automatically operable in response to entering movement of a docking rail on the bow of a boat;
(2) To provide such a docking device having means for automatically guiding the docking rail of the boat into position to be grasped by pressure-responsive grapple;
(3) To provide such a docking device embodying a grapple that is automatically operable in response to the pressure of an entering docking rail to grasp and hold the rail so as to tether the boat to a dock;
(4) To provide such a docking device having cushioning means to absorb the shock of entering movement of the docking rail;
(5) To provide such a docking device having means for manually releasing the docking rail from the grapple;
(6) To provide such a docking device having means for automatically adjusting the level of its grapple to the proper level for engagement of the docking bar on the bow of a boat;
(7) To provide such a docking device which is of simplified and lower-cost construction than former devices of this general type.

230. Ohkusu, M., *"Ship Motions in the Vicinity of a Structure,"* presented at First International Conference on the Behavior of Off-shore Structures (1976).

The equations of hydrodynamically coupled motions of a ship floating alongside a structure are proposed, together with expressions for hydrodynamical coupling forces between them. An expression for drift force on a ship is also presented, in which coupling effects between a ship and a structure are taken into account. Comparison between the computed results and experimental data shows, for the most part, good agreement.

231. Olsen, Ralph A., Cuthbertson, Robert H., *"Linked-Spar Motion-Compensated Lifting System,"* Dept. of the Navy, US PATENT-4 543 070 (Sep 1985).

An improved system for operating a lifting cable over the side of a ship at sea in which a spar buoy having an adjustable lifting capacity is coupled to the ship by a rigid linkage which is free to pivot on an axis attached to the ship deck, and operates to decouple the motion of the ship from the lifting cable. The spar buoy is attached to a gimbal sheave assembly having a disengageable connector and tension line for drawing the connector into engagement with a mating socket at the outward end of a linkage boom. A narrow upper section of the spar buoy is provided with a plurality of vertical tubes and valves which by flooding or evacuating operate to vary the effective water plane area of the buoy for continual tuning and optimally adjusting of its natural heave mode characteristics.

232. OPTEVFOR, *"Temporary Container Discharge Facility-Evaluation Report,"* Navy Operational Test and Evaluation Force (Apr 1981).

233. Packer, Martin R., *"Wave-Motion Compensating Apparatus For Use In Conjunction With An Off-Shore Crane, Or The Like,"* US PATENT-4 098 082 (Jul 1978).

Wave-motion compensating apparatus for a crane is provided, which includes a hydro-pneumatic

accumulator and an hydraulic ram, and additional components for controlling the fluid connection between the accumulator and the ram. The apparatus is intended to be coupled to a crane on an off-shore oil drilling rig, or the like, and it serves to compensate for the rising and falling wave motion between a vessel being unloaded and the crane. The compensating apparatus initially cause the load carrying cable of the crane to be maintained at a slight substantially constant tension permitting the load to rise and fall with the motion of the vessel. The apparatus at this time extracts, and stores energy from the up and down motion of the load; then, after a few up and down cycles, the apparatus exerts a lifting force on the cable to lift the load clear of the crest of the next wave. The foregoing is achieved without the need for any external energy source apart from the wave motion itself. The crane then takes over and the energy stored in the compensating apparatus slowly bleeds away, and the apparatus is returned to a reset condition for the next load.

234. Parks, M.H., "*Stabilization Of A Floating Platform*," US PATENT-2 889 795 (Jun 1959).

The present invention is directed to stabilization of a floating marine structure. More particularly, the invention is concerned with a floating marine structure provided with a platform from which marine operations may be conducted. In its more specific aspects, the invention is concerned with a stabilized floating platform which maintains an even keel in rough water.

The present invention may be briefly described as a floating structure adapted for use in marine operations which comprises a plurality of interconnected floats open on their lower ends and closed on their upper ends. A platform subjected to unequal loading is supported on the upper ends of said floats. Means are connected to the floats for maintaining a selected and different pressure on each of said floats depending on the loading of said platform whereby a substantially equal upward thrust is exerted on the platform by the floats to provide stability to the structure.

235. Parnell, P.E., "*Dynamic Load Compensation System*," US PATENT-3 343 810 (Sep 1967).

This disclosure is concerned with a system for automatically maintaining a substantially constant tension on a cable which supports a dynamically changing load. The disclosure describes a system including two sets of sheaves, one of which is stationary and other being movable. The cable is guided through the sheaves to support a load such as scientific instrumentation which may be lowered over the side of a ship, for example. The movable set of sheaves as described in the disclosure is positioned by actuation of a main cylinder controlled by a valve system responsive to a load which senses changes in the cable load and causes additional cable to be paid out or reeled in accordance with the instantaneous load. Additionally, the disclosure describes how the static load is automatically compensated for independently of the sensed dynamic load and the remainder of the arrangement for compensating for changes in such dynamic load.

236. Patel, M.H., Scheepsbouw and Scheepvaarttechniek Tech. News, No. 412, pp. 189-190 (Jun 1986).

A type of motion suppression system that significantly reduces the wave induced heave, roll and pitch of monohull crane vessel is described. The vessel is fitted with four motion suppression tanks mounted internally on each side. The tanks are open to the sea at the bottom and extend through the still water level so that a water piston exists in the chamber. Butterfly valves allow connection to the atmosphere of closure of the air spaces above the tanks internal watch levels. Open bottomed tanks modify wave induced roll motions and can also balance keeling movements on the vessel. On a semi-submersible annular open bottom tanks are mounted on the vertical columns and extend some distance above and below the normal operating line.

237. Patel, M. H. and J.H. Harrison, J. Sound and Vibration, Vol. 106, No. 3, pp. 491-507 (May 8, 1986).

This paper describes experimental and theoretical work on a passive motion suppression system for semi-submersible vessels. The system incorporates a pneumatic compliancy which is designed to enhance the wave induced motion characteristics of such a vessel for offshore drilling and production service. The pneumatic compliancy is achieved through the use of open bottom tanks mounted on the vessel. The tanks pierce the water surface and trap a volume of air above their internal water level. During operation wave action on the tanks imparts an oscillating vertical force on the vessel which is 180° out of phase with the inertia dominated wave induced heave force. As a result, vessel heave, roll and pitch motions are substantially reduced. Regular and irregular wave tests have been performed on a scale model enabling the motion reduction capabilities of such a system to be evaluated. Test data is compared with a multi degree of freedom dynamic response calculation in the frequency domain in which the Morison equation is used for calculating wave induced drag and inertia loads on the semi-submersible. The paper is concluded with a discussion on the relative merits and drawbacks of incorporating a pneumatic compliancy into hitherto hydrodynamically rigid semi-submersible designs.

238. Patel, M.H., DT. Brown, and J.A. Witz, *"Operability Analysis for a Monohull Crane Vessel,"* Institute of Naval Architecture Supplemental Paper, pp. 103-113 (Jul 1987).

The use of a crane vessel for the installation of fixed structures in the North Sea is a crucial weather sensitive part of the development of an offshore oil field. This paper presents calculations leading to the definition of operability for a monohull crane vessel. ITM CHALLENGER, of 43,500 tons displacement which is presently under construction for ITM (Offshore) Ltd. Wave induced forces and moments acting on the vessel are used in conjunction with a mathematical model of the vessel, crane and lift wire elasticity and the pendulum swing of the hook load to deduce the coupled motions of the vessel and the hook load as well as to derive the magnitudes of vertical and lateral inertia forces on the crane jib. These results are used to derive a typical operability curve for the crane vessel. The potential Mathieu instability is also investigated and an envelope of conditions for stable motions is presented.

239. Patel, Minoo H, *"Reducing the Wave Induced Motions of Offshore Vessels,"* Marine Engineering Review, pp. 22-23 (Apr 1986).

Excessive wave-induced motions can prevent semi-submersible or monohulled offshore vessels from carrying out production duties. However, a new motion suppression system has been developed to reduce these motions significantly and ensure maximum stability.

240. Patel, M.H., *"Vessel Having Stabilizing System,"* US PATENT-4 582 014 (Apr 1986).

A vessel, for example a semi-submersible is provided with at least a chamber for stabilizing it against any of all of heave, roll and pitch. The chambers are mounted on or in the vessel and disposed to lie at least partly below the surface of the water. Valves are provided for controlling the buoyancy of the chambers. Each valve has a first position in which the respective chamber is connected to atmosphere to permit air to enter or leave the chamber, and a second position in which the chamber is not so connected.

241. Person, A. and V.E. Bolding, *"Heave Compensation Apparatus for a Marine Mining Vessel,"* Global Marine Inc., US PATENT-3 943 868 (Mar 1976).

A ship in which a string of heavy pipe is raised or lowered vertically beneath the ship at a substantially constant velocity in spite of heaving movement of the ship. The equipment for raising and lowering the pipe string is supported by the vessel through heave compensation means that permits vertical movement of the ship relative to the pipe raising and lowering mechanism. The heave compensation means is a passive damped pneumatic-hydraulic spring system for isolating the vertical movement of the ship from the pipe raising and lowering equipment. The spring system operates over a very wide range of load imposed by the raising, lowering and supporting of a very long heavy pipe string.

242. Person, A., V.E. Bolding, *"Heave Compensation Apparatus for a Marine Mining Vessel,"* Global Marine Inc., US PATENT-4 039 177 (Aug 1977).

243. Petoia, Salvatore R., *"Report of Drop Test-Container Offshore Transfer System,"* Naval Weapons Handling Station (Dec 1979).

When a Crane-on-Deck (COD) or Temporary Container Discharge Facility (TCDF) is use to transfer containers from a containership to lighters alongside, the possibility of damage to the container and its contents always exists because of relative motions and pendulation. A series of tests were conducted to assess the container's structural limits and the shock levels imparted to the container and its contents as a result of the impact. During testing the containers were dropped from heights which had been calculated to provide representative impact velocities onto a concrete pad, and the appropriate data recorded. Additional teats included drops onto a resilient foam surface in order to evaluate the effectiveness of passive shock mitigation.

244. Polyakov, Anatoly, Ulitsa Gagarina, Ivanovich Evgeny, Alexi Petrovich, and Ulitsa Kholoby Stava, *"Cargo Crane,"* US PATENT-3 591 022 (Jul 1971).

A cargo crane for transporting cargo from one object to another object under conditions of the mutual vibration of objects, particularly ships operating under rough sea conditions, in which cargo ropes, a horizontally mounted jib and a suspension define an imaginary isosceles truncated pyramid, with the ropes being so connected to the system following up the mutual vibration of objects as to provide equal tension of the ropes, thereby ensuring non-impact and a precise placing of the cargo.

245. Pope, W.S., J.M. Harris, A.M. Plummer, J.E. Drennan, and H.D. Harrison, *"Relative Motion Sensing Concept Review,"* Battelle Columbus Laboratories (Jun 28, 1976).

The objective of this concept review program was to identify a preferred candidate system for sensing relative motion in 3 axis suitable for fabrication and evaluation in "breadboard" form ia a subsequent program.

246. Pope, W.S., J.M. Harris, A.M. Plummer, and D. Ensminger, *"Summary Report on Relative Motion Sensing Concept Review,"* Battelle Columbus Laboratories (Jun 1976).

The objective of this concept review program was to identify a preferred candidate system for sensing relative motion in 3 axis suitable for fabrication and evaluation in "breadboard" form in a subsequent program. Of the systems studied, two were selected for further development and two were proposed as back up or reserve systems in the event that unforseen difficulties precluded

development of either of the two primary systems. For the primary systems, a multiple tag line is proposed to sense relative motion in the horizontal plane, and an accelerometer based system for sensing vertical relative motion. The backup or alternate systems are: an acoustic Doppler sensor and a single tag-line follower servo system, both for relative vertical motion.

247. Powell, G.E., "*Pneumatic Stabilizer For Vessels*," US PATENT-1 220 551 (Mar 1917).

This invention relates to improvements in vessels and especially with reference to pneumatic stabilizers for use on opposite sides of a vessel to prevent the vessel from being rolled excessively by the action of the waves in a sea way, the object of the invention being to provide stabilizing devices of this class which are extremely simple in construction, which may be readily installed in a vessel either after the latter has been built or while the vessel is in course of construction and which act automatically to stabilize the vessel and minimize the rolling thereof by the waves.

248. Prud'homme, John W., James R. Robertson, and Richard C. Fisher, "*Transloader*," US PATENT-3 309 065 (Mar 1967).

The invention relates to means primarily for use with two relatively moving bodies or supports in connection with the transfer of a load between them, the arrangement being especially designed to compensate for relative vertical movement between the supports during such transfer.

It is therefore an object of the invention to provide a transloader which can be utilized in connection with an operation of the described sort and which automatically will compensate for or adjust to the relative vertical motion between two supports so that the load is automatically moved in accordance with the motion of the vessel onto which it is being loaded or is automatically moved there from so that the strain on the cable is kept within bounds and so that the distance between the vessel and the load increases in a controlled, expected way.

249. Reddy, D.V. (Coastal and Oceanographic Engineering Department), D.B. Muggeridge, A.S.J. Swamidas, M. Arockiasamy, H. El-Tahan, and C.C. Hsiung (Memorial University of Newfoundland), "*Dynamic Response of Moored Semi-submersibles to Bergy Bit Impact, Irregular Wave, Wind, and Current Forces,*" in: Offshore Technology Conference Proceedings, OTC Paper 824,425 (May 1982).

The paper describes initial studies on the motion and structural response of a typical semi-submersible to wind, wave, current, and bergy bit impact forces. The semi-submersible is idealized as a space frame model, and the deck discretized using equivalent stiff beam elements and distributed member weights. Pierson-Moskowitz Davenport spectra are used for wave and wind forces respectively. The 100-year design criteria are based on available environmental parameters in the Hibernia region. Responses to simulated wave excitation on a 1 to 70 model, in the wave tank at Memorial University of Newfoundland, agree well with the calculated values; wind and current forces are applied as static loads in the model.

250. Reid, Gordon J., "*Anti-Friction Buffer*," US PATENT-3 163 410 (Dec 1964).

This invention relates to an anti-friction buffer, particularly for boats, but which may be used for other purposes and which uses the castered wheel principle as its frictionless component.

The present invention seeks to overcome these drawbacks by providing a buffer of the castered wheel type which will not only absorb the impact of a docking boat but will greatly reduce or

eliminate the turning moment created by the thrust upon the castered wheel, thus allowing the wheel to caster freely at all times.

The present invention consists essentially of an anti-friction buffer for use between relatively moving elements comprising a mounting base adapted to be mounted on one of the said elements, a spindle rotatably and longitudinally slidably mounted on the said base, resilient means on the base normally urging the spindle to an outer position thereon, a roller carried at the outer end of the spindle with its axis offset in relation to the spindle axis, bearing means carried by the spindle radially outwardly from its axis at least as far as and on the same side of the spindle axis as the roller axis, said bearing means being adapted to engage said one element when a thrust is applied to the periphery of the roller by the other of the said elements, to take the resultant thrust, while allowing the roller and spindle to function as a caster.

251. Reynolds, Thomas J. and James P. Blanchet, "*Crane Hook Heave Compensator And Method Of Transferring Loads*," US PATENT-4 003 472 (Jan 1977).

A floating barge crane that is provided with a heave compensator package between the traveling block of the crane and the load hook of the crane and with the package containing substantially all of the components of a hauldown system. The hauldown system includes four winches which carry hauldown cables that pass from the package to the load and to the stationary structure at circumferentially spaced points to pull the load toward the stationary structure and control lateral, vertical and rotational movement of the load.

252. Ross, Jonathan M., *"Flopper Stoppers in Ocean Research,"* Journal of Naval Engineers, Vol. 92, No. 1, pp. 45-50 (Feb 1980).

"Flopper Stoppers" compose a simple passive system for decreasing the rolling of a ship dead in the water at sea. In this paper, expressions are developed that may be used for designing "Flopper Stoppers." One expression gives the decrement in roll angle caused by the "Flopper Stoppers." Other expressions give stresses on the suspension system and the ship by the damper plates.

253. Rossignal, Grant A., *"MS CYGNUS, SS AMERICAN TROJAN, and Causeway Platform Facility Relative Motion,"* DTRC SPD-515-03 (Feb 1983).

This report presents the results of relative motion trials conducted in support of RO/RO ship interface operations. The extent to which relative motions impose limits on causeway platform facility (CPF) operations is evaluated. The CPF was operated stern-moored to the MS CYGNUS, side-moored to the SS AMERICAN TROJAN, and underway while in transit. Variations of the CPF configurations were also evaluated. The results of these trials show that ship/CPF relative motions should not impact interface operations for significant wave heights up to 2.2 feet (0.7 meters). Stern and side moorings were successfully conducted under fairly mild environmental conditions, with the stern mooring providing the greatest CPF sheltering from incident waves. Limitations of existing configurations did not permit CPF and causeway ferry (CWF) operations to be conducted for significant wave heights greater than 3 feet (0.9 meters). LCU/CWF to CPF relative motions will have greater impact on limiting future RO/RO ship interface operations than will ship/ramp/CPF relative motions.

254. Rucker Shaffer, *"200 Ton Crane Motion Compensator Product Description,"* Rucker Schaffer (Nov 1976).

255. Ruth, Lawrence C., *"An Investigation of the Absolute Lighter Motions Involved in the Container Offloading and Transfer System (COTS) Trials,"* DTRC SPD-515-02 (Mar 1976).

Ship motion and wave measurements were conducted for various lighters participating in container offloading and transfer system (COTS) trials off Coronado Island, San Diego. Their purpose was to evaluate the effects of waves and lighter motions on the offloading and loading procedures. Motions of a warping tug causeway system, an LCM 8, and a LCU 1652 were measured while they were alongside a bumper system connected to an elevated causeway. All lighter motions were seen to be very small due to low seas predominant at the time of the trials.

256. Ryan, W.J., *"Combined Marine Ramp Transfer and Mooring System,"* Ryan Ramp, Inc., US PATENT-4 003 473 (Jan 1977).

A ramp transfer and mooring system for the transferring of personnel and/or material between two relatively moving objects, such as for example from a boat to an offshore platform, wherein the ramp system permits the safe transfer between the two by a unique, flexible but at least relatively solid design which has the capability of twisting and turning to offset the relative motion and which adjusts the relative motion to a gradual change between the two, and yet still has the capability and solidity to moor and help stabilize any sudden rolling action of the boat. The ramp transfer and mooring system of such a first exemplary embodiment includes six basic elements - the ramp structure itself, the connection means between the ramp and the boat, and the connection means between the ramp and the stationary platform including a swivel head system, a king post/pivot deck structure, and an enclosed counterweight system. A novel system of connecting the ramp to the boat , a special tieback system for storing the ramp during storms, and an alternate ramp structure are also disclosed.

In an alternate embodiment of the invention, the novel transfer ramp system is composed of three elements - the ramp structure and the two connection means between the ramp and each of the boats - and, having cable stringers, has the capability of being rolled up for storage. This alternate embodiment is a system for, for example, the transfer of personnel and/or material between two objects, both of which move, such as two boats. An alternate flexible ramp structure is also disclosed.

In another alternate embodiment of the invention, the system has for components - the ramp structure, the connection between the ramp and boat, the connection means between the ramp and the stationary pole platform, and external counterweight means - to permit, for example, the transfer of personnel from a beat to a single stationary pole platform or, for example, for transferring fuel between a tanker and a "superport" type facility located offshore through additional piping means.

In still another alternate embodiment (boat/barge), the system has four components - the ramp structure, the connection means between the ramp and a relatively stationary barge, the connection means between the ramp and the boat, and a counterweight dampening structure.

257. Samra, B.S., *"A Predictor/Controller System for Landing Operations in Rough Seas,"* ASME, Presented at The Sixth International Symposium and Exhibit on Offshore Mechanics and Arctic Engineering (Mar 1987).

The uncertain behavior of marine vehicles/structures subject to random wave and wind forces makes the "land on" task for helicopters or even simple crane-barge cargo transfer difficult. It is not easy for an operator to assess and act upon the relative motion of two independently moving

bodies.

Predictions of deck motion could help to accomplish such tasks and for this purpose we introduce an adaptive prediction algorithm. The program described optimises its internal parameters to generate improved predictions and adapts to changing sea spectra.

The predictor output can be either used as an operator guide to aid decision-making or incorporate directly into a control system. In this paper we describe the application of the predictor as an operator guide for a helicopter landing policy.
Direct prediction incorporation into a control scheme is considered for the problem of landing a load with minimum impact velocity on heaving deck. The control problem is formulated as an optimization problem where the initial position and velocity of the load is know and the final desired position to achieve zero impact velocity is determined by the adaptive predictor.

258. Sanders, Raymond J., *"Heave Compensating Cranes,"* US PATENT-4 021 019 (May 1977).

A crane for ships and having a boom pivotally mounted for vertical movement on a base, telescopic hydraulic jack means connected to the boom to support the outer end thereof in a desired position, a pulley carried by the boom near the outer end thereof and means for shifting the pulley towards and away from the base, a cable threaded over the pulley and winch means for reeling in and paying out this cable, and a control system including accumulator means connected to the jack means for maintaining the boom outer end substantially in the position thereof regardless of ship motion under wave action when the cable is supporting a load in the water.

259. Sankar, S. and J. Syoboda, *"Active Stabilization of a Ship Borne Crane,"* 51st Symposium on Shock and Vibrations, USA (Oct 21-23, 1980) 237-247.

This paper presents the dynamic performance of an active-stabilizer for controlling a ship-borne crane under heavy weather. The governing equations are derived and solved using digital simulation. The mathematical model served as a basis for the dynamic design study of the crane system. The active-stabilizer for the crane uses a heavy compensating boom to decouple the submersible from the motion of the support ship. The motion compensation system uses an active servo-control system operating in parallel with a soft hydro-pneumatic spring. The crane boom maintains its position in respect to the shore by monitoring both the acceleration of the boom tip and the boom angular position. The active compensation system consisting of a linear hydraulic servo actuator coupled in parallel with a hydraulic accumulator allows for adjustment of the gas prechange pressure according to the load. The study indicated that the sizing of the actuator system and its adjustment capability significantly affects the energy requirements of the active damping servo actuator system.

260. Sawaragi, Toru, Shin-ichi Aoki, and Masayoski Kubo, *"New Mooring System to Reduce Ship Motions and Berthing Energy,"* Coastal Engineering in Japan, Vol. 27, pp. 303-313 (Dec 1984).

In this paper, the improvement of mooring system in a harbor often attacked by storm waves is discussed by numerical simulation. First, it is pointed out that the ordinary mooring system which consists of fenders and mooring lines is not suitable for a ship moored to a quay from the viewpoint of ship motions and mooring forces. The inferiority of asymmetrical mooring and the effectiveness of the use of dash-pots are discussed. Then, the optimum mooring system in a harbor with respect to ship motions is proposed. These investigations are performed by numerical simulation for regular waves.

261. Sayer, P. and R. Spencer, *"The Wave-Induced Motions of Adjacent Floating Vessels,"* paper presented at International Symposium on Hydrodynamics in Ocean Engineering at the Norwegian Institute of Technology (1981).

262. Scheffer, H. J., S. Kolhase and O. Burkhardt. Proc. Int. Conf. on Coastal and Port Engineering in Developing Countries, Vol. 1, pp. 570-579 (Mar 20-26, 1983).

Describes studies on wave effects for harbor breakwater design and layout at Puerto Moin, Costa Rica. Discusses analysis of wave height parameters, and describes hydraulic model experiments to evaluate the theoretical analysis. Notes results of ship motion studies and suggests that the vertical motion of the ship is the important criterion in evaluation of breakwater dimensions.

263. Scheffer, H.J. and S. Kohlhase, *"Functional Harbour Design Under Consideration of Ship Motions,"* International Conference on Numerical and Hydraulic Modelling of Ports and Harbours, pp. 221-229 (Apr 23-25, 1985).

In addition to investigations concerning the protective function of a harbor, economical optimization requirements are gaining increasing importance. In this respect, investigations of wave-induced motions of berthed vessels have become an important demand in harbor design. The statistics of certain tolerable ship motions and extreme values become decisive in respect to functional harbor design. Some remarks on hydraulic investigations on wave attenuation in harbors, including operational and freight-handling requirements, are given and a basic investigation program on ship motions is briefly discussed. For discussion purposes, the results of investigations with irregular waves (oblique approach) concerning a container vessel at typical harbor pier constructions are included.

264. Schimmeyer, Werner K., Norman J. Wood, and Joseph V. McCargar, *"Ram Tensioning Device,"* US PATENT-3 871 527 (Mar 1975).

A ram tensioning device comprising a hydraulic-pneumatic cylinder with a free piston disposed within the cylinder, a piston rod extending from one end of the cylinder the piston rod being acted upon by pneumatic fluid to provide shock absorbing tensioning for a hoist cable and being acted upon via the free piston by a hydraulic fluid to provide accurate positioning of the piston rod to assist in handling heavy variable loads which are ideally subjected to a constant tensional force in one mode of operation and firmly positioned in another mode of operation.

265. Schrader, William L., *"Freight Container Unloading System,"* Dept. of the Navy, US PATENT-4 049 131 (Sep 1977).

266. Scotch, J.P. and M.J. Gollobin, *"Crane-On-Deck (COD) Selection Process 009, Final,"* Presearch, Inc. Report No. 316 (Oct 29, 1976).

This study assesses the concept of using mobile cranes on the deck of non-self-sustaining containerships to discharge containers and thereby serve as extensions to naval auxiliary assets. The report summarizes the work performed in the three phases of the crane-on-deck (COD) study, which (a) describes the operational concepts envelope for assault follow-on echelon (AFOE) and Marine amphibious brigade/Marine amphibious force (MAB/MAF) supply operations, (b) establishes operational performance requirements, and (c) develops an evaluation model for

comparing alternative COD systems. The work conducted for the Naval Coastal Systems Laboratory under Contract No. N61339-76-C-0075.

267. Seidl, L.H., R.D. Foreman, P.A. Beynet, and S.N. Singhal, "*Prediction of Stability, Mooring Load, and Motion Aboard Floating Platforms*," in: Offshore Technology Conference Proceedings, OTC Paper 5447 (1987).

This paper presents a computer system which combines state-of-the-art marine technology with a simple user interface to provide information vital to operations personnel for decision making. The marine technology discussed includes efficient, yet sophisticated accounting of the rig's loading condition, hydrostatic stability, assessment of hydrodynamic quantities, the actual mooring characteristics, and the automatic solution of the dynamic platform system to predict the platform's behavior in response to certain events. Such predictive capability, combined with experience, enables the contractor and the operator to work more efficiently towards a mutual decision.

This tool, referred to as the "On-Board System", was used by drilling personnel on two semi-submersibles in the Bering Sea. Its counterpart, in the office environment, may be referred to as "Rig Simulator", as it now simulates the dynamic behavior of offshore rigs.

In addition to the capability to predict stability, mooring load, and motion, the "On-Board System" provides a tool for the acquisition of a data base of environmental information and corresponding vessel response while on location for future comparative analysis of platform behavior.

268. Schellin, Thomas, "*Analysis of Vessels Moored in Shallow Unprotected Waters,*" Offshore Technology Conference 4243 (1982).

269. Shell, R.C. (Shell Oil Company) and A.H. Masso (Shell Development Company), "*Rough Weather Drilling Vessel Simulation,*" Shell Oil Company and Shell Development Company, in: Offshore Technology Conference Proceedings, OTC Paper 772,917 (May 1977).

The gulf of Alaska may have the roughest wave climate ever faced by the offshore oil industry. The high cost of time lost due to these rough seas was a major factor in selecting a floating drilling rig. This paper describes a simulation method that was used to estimate down times of floating rigs in the Gulf of Alaska and can be applied to other rough-weather areas.

The simulator has two parts: one that simulates operations and another that simulates weather interferences with those operations. While the model "drills a well," a novel weather model generates both wave heights and periods. Wave heights and periods determine vessel motions, which are checked against operating limits. If motions exceed the limits, work is "slowed down" or "stopped". By "drilling" - simulating - a large number of wells, reliable statistics on the down time of a particular rig are developed.

The weather model in the simulator can be applied to other offshore areas provided enough wave data exist. This approach also can be used for simulating offshore tanker loading, pipelaying or platform installations.

Further, the simulator can assess the valve of hardware improvements that permit operations to continue in rougher seas. Statistical tests on the weather model showed that it adequately simulated Gulf of Alaska sea conditions. Furthermore, rig down time calculated with the simulator proved to be more realistic than down times calculated with models using just wave height.

270. Simon, F., *"Lifting and Handling Equipment Unit, Especially for Shipside Operations,"* US PATENT-4 277 053 (Jul 1981).

Under the action of the relative motion between a hoisting machine support and a load, a movable component such as a pulley-block carried by the hoisting machine is capable of free displacement under gravity between two end positions of abutment when that end of the movable component which is intended to cooperate with the load is stationary with respect to the load, thereby compensating for any variation in distance between the load and that portion of the hoisting machine which carries the movable component. The equipment unit is designed primarily for hoisting operations performed at sea or on wharves.

271. Skaalen, Clifford I. and Arthur Rausch, *"Flexible Side Connector for Floating and Elevated Platforms,"* Dept. of the Navy, US PATENT-4 335 670 (Jun 1982).

A flexible side connector assembly comprising an in line flexural system having a plurality of rubber compression elements and a solid shear member. Both the adjacently aligned flexural member and the shear member have grooved solid heads at opposing ends of the assembly for insert of guillotines in opposing platforms which are to be coupled each to the other.

272. Society of Automotive Engineers, *"Rating Lift Cranes on Floating Platforms Operating in the Ocean Environment - SAE XJ-1366,"* (1985).

273. Soros, Paul and Bela Koman, *"Artificial Island Trans-Shipment Terminal,"* Soros Associates, in: Offshore Technology Conference Proceedings, OTC Paper 742,09 (May 1974).

The paper describes the planning, design, and construction of an artificial island trans-shipping terminal in the Atlantic Ocean, 8 miles from the coast of Brazil. At a connecting open-sea berth built along a 55-ft-deep natural channel, salt and other granular materials can be loaded into 100,000 dead-weight ton (DWT) be unloaded on the sheltered side of the island. Up to 150,000 tons of salt can be accumulated in the storage area.

Soros Associates established the feasibility of building and maintaining an artificial island in this equatorial part of the Atlantic Ocean on the basis of extensive investigations of wind and wave data, tidal movements, currents, and bottom conditions. Seismic surveys and soil borings were carried out before the final design of the island and of the pile-supported structures connected with it.

The solutions of technical problems encountered during the design and construction provide useful information for the planning of future artificial islands and offshore terminals.

274. Soros, Paul, and Bela Koman, *"Variable-Orientation Berth for Large Carriers,"* Soros Associates Consulting Engineers, in: Offshore Technology Conference Proceedigns, OTC Paper 824,399 (May 1982).

Ship berthing and loading studies were carried out for a high-capacity offshore terminal designed to load coal into 250,000 DWT ships, near Newcastle, New South Wales, Australia.

The resulting solution permits ships to berth at a varying angle in order to head into the waves to minimize wave-induced oscillations. Buoys and dolphins are used to rotate the moores ship and to pull it tight against the fenders to avoid bouncing and slamming, or to hold it off prevent contact between ship and fenders.

275. Soulant, H.A. Jr., *"Stabilization System for Water Vehicles, Platforms, and Structures in Wind-Maintained Seas,"* US PATENT-3 957 010 (May 1976).

A device for stabilizing a floating platform or the like from the roll of heave motions, imparted by wind-maintained waves and regular swells. The platform is supported on a plurality of buoyant pontoons horizontally spaced a variable distance apart in the direction of the wave system. Once the significant wavelength is approximated, the buoyant pontoons are moved to a spacing of a wavelength, of the significant wave, and then continually adjust to the possibly changing wavelength of the significant wave. These spacing, controlled from the wave system, stabilizes the platform because such spacing insures that the lifts from all pontoons at each instant in time are equal.

276. Stair, Leslie D., *"System To Transfer Cargo Or Passengers Between Platforms While Undergoing Relative Motion,"* US PATENT-4 180 362 (Dec 1979).

A carrier for cargo or personnel is transferred between an offshore platform and a landing platform on a vessel while subject, one with respect to the other, to vertical and lateral movements due to waves and wind within an envelope of motion. When the carrier is on the offshore platform, it is lowered by a crane from a constant tension level lifting winch to a point above the envelope of motion by the landing platform on a vessel. A trailing end of this cable is coupled to the cable of a downhaul winch having variable constant tension levels on the vessel. Slack is eliminated in the coupled cables and the carrier is caused to rise and fall with the movement of the vessel through a preestablished constant tension level by the lifting winch. Constant tension is developed in the coupled cables when the vessel moves toward the carrier within the envelope of motion while the downhaul winch is set at a higher tension level and zero winding speed. The carrier is then drawn onto the landing platform by energizing the downhaul winch to a desired winding speed at the higher constant tension level. Slack is eliminated from the coupled cables by energizing the lifting winch when the carrier and the lifting platform approach each other. The carrier is retained on the landing platform by energizing the downhaul winch to the higher constant tension level. The downhaul winch is then energized to a tension level less than the tension level of the lifting winch when the carrier recedes away from the lifting platform and when the carrier is lifted from the landing platform by the lifting winch. The cable take-up velocity is maintained at a value exceeding vertical relative motion between the platforms.

277. Starsmore, N. and S. Taggart, *"Offshore Pre-Planning of Motion-Sensitive Operations,"* presented at MTS Oceans '82 Conference (Sep 1982).

278. Stinson, P.L., *"Universal Mooring And Ramp,"* US PATENT-3 008 158 (Nov 1961).

This invention relates to a universal mooring and ramp, the ramp being intertelescoping and affording a universal connection to a swinging, pitching, rolling, and yawing vessel on a rough sea, the support for the ramp being self-adjustable to accommodate for variations in water level

and variations in vessel freeboard, and the platform from which the ramp extends being automatically traversable responsive to vessel movements. Such an invention solves a long unfulfilled need for means providing structure inherent within itself which can compensate for all of the stresses and strains heretofore imposed both upon vessels attached to ramps or mooring structures, and upon such ramps and mooring themselves, both under normal seaside and tidal affected conditions, and under storm and heavy weather conditions. The invention also minimizes hazard to goods carried thereon and to personnel traversing it, and includes safeguarding means in its own elements which protects it structurally from the heavy usage it must withstand.

It is therefore an object of this invention to provide a universal ramp and mooring which is adapted to compensate for the swinging, pitching, rolling and yawing of a water borne vessel connected thereto, and which compensates for variations in water level and for variations in the freeboard of a vessel or vessels attached thereto.

279. Stone, K., D. Walkers, T. Vaughters, and A. Rausch, *"The RO/RO Discharge Facility,"* SNAME Star Symposium (1984).

Department of Defense planning for logistics support to sustain major amphibious assault operations relies extensively on the utilization of U.S. Flag commercial shipping. Since the mid-1960's, commercial shipping has been steadily shifting away from breakbulk ships and toward containerships, Roll-on/Roll-off (RO/RO) ships, and barge ships, which were not intended to operate without extensive port facilities. However, amphibious assault operations are usually conducted over undeveloped beaches, and expeditious response times preclude conventional port development. Handling of vehicular cargo in this environment presents a serious problem. In response to this, the Naval Facilities Engineering Command has been tasked to develop systems for offloading merchant ships in stream.

280. Stout, G., M. Lyon (NCSC), and W. Culpepper (EG&G), *"Rider Block Tagline System Operation,"* NCSC and EG&G (Jan 1980).

281. Strengehagen, Jon and Sverre Gran, *"Supply Boat Motion, Dynamic Response and Fatigue of Offshore Cranes,"* Det Norske Vertas, in: Offshore Technology Conference Proceedings, OTC Paper 803,795 (May 1980).

An investigation of the dynamics of offshore cranes has been performed by means of finite element methods. It is shown how recognized theories for ships' response in irregular waves can be applied in a statistical approach for determining the vertical deck velocity for derating purposes. Methods for determining the fatigue life of offshore cranes based on the different types of load-cycles are presented. At last some practical considerations with respect to the application of the theories are given.

282. Stricker, P.A., *"Active/Passive Motion Compensating Crane for Handling a Remote Unmanned Work Station,"* Techwest Enterprises, Ltd., in: Offshore Technology Conference Proceedings, OTC Paper 783,236 (May 1978).

This paper describes the concept, analysis, design, and sea trials of an active/passive ten ton capacity motion compensating crane for deploying a remote unmanned work system. The same concepts can be employed to make possible the handling of tethered loads, including ship to ship

transfers, in high sea states without the risk of cable failure or excess payload pendulation. Motion compensation is achieved by driving the boom up and down, while the ship is heaving, such that the boom tip remains substantially stationary with respect to a fixed point on earth. The combination of active and passive boom control resulted in significant savings in power consumption over a purely active system while providing excellent motion compensation. The crane, mounted at the stern of a salvage tug, has a reach of 30 feet (9 m), a boom tip stroke of 24 feet (7.3 m), and can deploy the vehicle over the side or stern. A travelling saddle on the boom positively restrains the payload during deck handling operations while moving the load inboard or outboard. The cable storage reel accommodates over 23,000 feet (7000 m) of Kevlar-wound electromechanical cable, and the entire crane can be disassembled into modules for air transportability. Performance data is provided for a sea state four operation, based on computer simulation predictions.

283. Strolenberg, W.J., *"Apparatus for use in Raising or Lowering a Load in a Condition of Relative Motion,"* US PATENT-4 025 055 (May 1977).

Motion compensating apparatus for use on marine vessels. Apparatus includes means for maintaining tension in load lifting member during relative motion and means for locking the tension means in one direction of motion. Tensioning means includes high and low pressure accumulators which enable compressed fluid to act on linear or rotary drives to apply high and low tension. Load rises and falls with vessel under high tension but weight is mainly offset. Locking means, such as ratchet and pawl or pilot-operated valve, is selected to lift load from vessel at crest of relative motion. Tension can be applied with linear ram, rotary drive or through differential drive.

284. Summey, D.C. and T.C. Watson, *"Comparison of Computer Response Amplitude Operators for Containerships, Lighters, and Barges,"* NCSC Report TM 432-82 (Feb 1982).

Response Amplitude Operators (RAO) are predicted by two ship motion computer models for four container vessels, two discharge lighters, and two barges. The response of each vessel in surge, heave, sway, pitch, roll, and yaw is computed as a function of wave exciting frequency for head, quartering, and beam seas. A secondary objective is to compare the response amplitude operators predicted by the two available ship motion computer models. The data are presented in graphical form with motion response for each degree of freedom plotted versus exciting frequency. Motions were computed for all vessels in a lightly loaded configuration while the containership motions were computed for a heavily loaded condition.

285. Summey, D.C. and T.C. Watson, *"Seaway Response of a Crane Mounted on a Type-B DeLong Barge Under Various Crane Loading Conditions,"* NCSC Report TM 276-80 (Jan 1980).

286. Techwest Enterprises, *"Final Report on the PMC-Winch Constant Tension Design Study,"* (Nov 1983).

287. Techwest Enterprises (B. C. Research) *"Motion Compensating Winch Systems,"* (Apr 1977).

288. Thomas, D.G., *"Stabilized Floating Platform,"* US Energy Research and Development Administration, US

PATENT-3 978 805 (Sep 1976).

The subject invention is directed to a floating platform for supporting nuclear reactors and the like at selected offshore sites. The platform is provided with a stabilizer mechanism which significantly reduces the effects of wave action upon the platform and which comprises a pair of relatively small floats attached by rigid booms to the platform at locations spaced therefrom for reducing wave pitch, acceleration, and the resonance period of the wave.

289. Thomas, W. D. R. and M. Davenport, "*Remotely Operated Vehicles,*" ROV '83 Conference and Exposition Proceedings, pp. 223-229 (Mar 14-17, 1983).

Current trends in the offshore industry suggest that active motion compensating cable handling systems may become standard equipment with many of the latest generation of Remotely Operated Vehicles (ROV), particularly those destined for use at very great depths. This paper discusses this increasing need for motion compensation and reviews the approaches to motion compensation which are presently available. It then describes in some detail advances which have been made by Techwest in developing a product-line of ROV handling system which are as simple and compact as those systems currently in use and which provide the most advanced motion compensation available at this time.

290. Traffalis, J.J., "*Container Offloading and Transfer System (COTS): Technical Evaluation of Temporary Container Discharge Facility (TCDF),*" NCEL Report TN-1625 (Mar 1982).

The report gives the results, findings, conclusions, and recommendations of a Technical Evaluation of the TCDF crane; describes the equipment, preparations, and tests required for Technical Evaluation of the TCDF crane; and also presents a chronology of events leading from the desired TCDF configuration of two cranes on a suitably sized hull to a single crane on a deactivated LSD hull for Technical Evaluation.

291. Traffalis, J.J., "*Power Tagline Development,*" NCEL (May 1, 1975).

292. Turner, C.R., "*RO/RO Causeway Platform Facility Off-Loading Performance in Sea State Three,*" DTNSRDC/SPD-1138-01 (Jun 1985).

Seakeeping experiments were conducted to evaluate the Sea State 3 capabilities of a roll-on/roll-off (RO/RO) ship offshore off-loading system intended for use in the logistical support of operations over beaches without developed port facilities. Two systems were tested to model the assembly and execution stages of the off-loading operation. The assembly stage consisted of a RO/RO ship to which was moored a causeway platform facility composed of six causeway sections; the latter were moored in a configuration of two connected end-to-end by three abreast. The second stage modeled the complete setup used for off-loading operations. It employed, in addition to the above platform, a causeway ferry consisting of three pontoon sections in single file connected to the aft end of the platform, and a ramp installed from the ship to the platform.

293. Turner, C.R., "*Zero Speed Seakeeping Characteristics of a Causeway Ferry Consisting of Four Pontoons Connected End-To-End,*" DTNSRDC/SPD Report 1075-01 (Jun 1983).

Seakeeping experiments were conducted to evaluate the performance of a causeway ferry consisting of four pontoons connected end-to-end which would be used to transport cargo from a floating platform to the beach during container-ship off-loading in support of assault operations where no port facilities exist. The aft pontoon contains propulsion units to drive the ferry with the forward three pontoons being assembled from standard watertight cans. Heave, roll, and pitch of the aft pontoon, heave of the forward pontoon, and the relative angular displacements between individual sections were measured in random and regular waves at zero speed for unloaded and loaded conditions. A spectral analysis of the random wave data was performed to yield transfer functions for comparison with transfer functions obtained from the regular wave runs. Values of significant double amplitudes from the random wave runs are also reported. In general, transfer function and significant double amplitude results for the two displacements are not greatly different, although in the loaded condition, the causeway ferry did experience considerable deck wetness for headings between beam and bow quartering. Performance improved as heading angle increased and was best in head seas.

294. T.Y. Lin International, *"Navy Floating Pier: Investigation of Dynamic Motions, Ramp Supports and Flexible Utility Connections,"* T.Y. Lin, International CR83.030 (Jun 1983).

The feasibility of a floating pier concept for Navy surface combatants has been investigated further by studying the dynamic motions of the pier and by producing preliminary designs of the ramp supports and flexible utility connections. The dynamic motions of the pier were analyzed for the loading cases of berthing impact of ships, waves generated by passing ships, waves created by storm conditions, long period seiche waves and ground motions from seismic events. For all realistic loading cases, the motions of the pier were reasonable and would not present problems to personnel or equipment operating on the pier. Practical designs have been produced for the ramp supports and flexible utility connections.

295. U. S. Department of Defense, *"Offshore Discharge of Containership II (OSDOC) II Test and Evaluation 3-14 October 1972,"* Evaluation Section, Joint Army-Navy Test Directorate (May 1973).

The primary purpose of OSDOC II was to test the means available to offload a non-self-sustaining containership in an open sea environment. Both adopted and developmental equipment were examined. Procedures were developed and tested for discharging containers and outside cargo from non-self-sustaining ships. During the underway replenishment portion of the test, the containership discharged palletized cargo and containers to another ship while both vessels were underway. During the surface discharge portion of the test containers and outside cargo were discharged across the beach while the containership was swing-moored 1 mile offshore. Systems applicable to the short range future (1973-77) were tested. Problem areas were examined for the purpose of guiding related future research and development.

296. U. S. Department of the Navy, *"Navy Decision Coordinating Paper for the Containe. Offloading and Transfer System (COTS),"* NDCP-YP816SL, Chief of Naval Operations (Jul 1975).

297. U.S. Department of the Navy, *"Replenishment at Sea,"* Office of the CNO, NWP 14 (Rev. D).

In order to carry out the Navy's mission, fleet units must be capable of remaining at sea for prolonged periods, fully ready to carry out any assigned tasks. Units of the mobile logistic

support force (MLSF) are equipped to replenish combatants underway with fuel, ammunition, provisions, stores, and spare parts.

298. Van Den Bosh, J.J., *"A Free Surface Tank as an Anti-Rolling Device for Fishing Boats,"* Third FAO Technical Meeting on Fishing Boats, paper TMB-2/1 (Oct 1965).

299. Van Oortmerssen, G., J.A. Pinkster, and H.J.J. van den Boom, *"Computer Simulation of Moored Ship Behavior,"* Waterway, Port, Coastal, and Ocean Engineering, Vol. 112, No. 2, pp. 296-308 (Mar 1986).

A model is described for the prediction of motions and mooring loads of ships and other floating structures moored in irregular waves, wind, and current. The mathematical model is based on the equations of motion in the time domain. This approach allows nonlinear and asymmetric mooring loads and arbitrarily in time varying excitation of the vessel. Input variables are: environmental conditions, mooring layout; elasticity characteristics of mooring lines and fenders; and geometry of the vessel. Output information includes: time histories, spectra and statistical values of motions, and mooring loads. Results are presented of an extensive validation study on the behavior of a 200,000 TDW tanker moored to an offshore jetty in shallow water.

300. Van Oortmerssen, G., *"Hydrodynamic Interaction Between Two Structures, Floating in Waves,"* paper presented at Second International Conference on the Behavior of Offshore Structures, England, pp. 339-356 (1979).

If two structures are floating in waves in each other's vicinity, the fluid loading on the separate bodies will be influenced by the presence of the neighboring structure. The wave loads on a body are affected, due to sheltering or wave-reflection effects caused by the neighboring floating body, while extra loads are exerted by the radiated waves, which are generated by the motions of the neighboring body. Also, the hydrodynamic forces due to the body's own motion will be different when another body is present. Besides a general description of the interaction effects, experimental data on interaction forces, obtained from model tests, are presented and compared with theoretical data.

301. Van Oortmerssen G., *"Some Hydrodynamic Aspects of Multi-Body Systems,"* paper presented at International Symposium on Hydrodynamics in Ocean Engineering, Norway, pp. 724-744 (1981).

302. Voase, Thomas R. and Frederick B. Callanen, *"Combination Gangplank And Fluid Transfer Apparatus,"* US PATENT-3 228 051 (Jan 1966).

This invention relates to a combined gangplank and fluid transfer apparatus for use in connection with the loading and unloading cargo from oil tankers, gasoline barges, and the like.

It is and object of this invention to provide a more convenient apparatus for the handling of fluid cargo than has heretofore existed. Another object of this invention is to provide a unitary assembly which serves as both a gangplank and fluid transfer conduit.

303. Wang, S.S., *"Crane Load Decoupler for the Elevated Causeway (ELCAS),"* NCEL Report No. TN-1716 (Dec 1984).

This report documents the development efforts made on the load decoupler of the container handling crane for the elevated causeway (ELCAS) portion of the Container Offloading and Transfer System (COTS). A prototype oleo-pneumatic crane load decoupler was test-evaluated and found to be unsatisfactory. A second-generation load decoupler was designed after reexamining the original design criteria and performance requirements. A liquid spring/damper type load decoupler was selected as the second-generation load decoupler. This device was test-evaluated and was found to meet the specified performance requirements and to be compatible with the ELCAS crane for container handling operations. It is recommended that the load decoupler be procured as an accessory of the ELCAS container handling crane and that field performance continues to be monitored for possible improvement.

304. Ward, C.C. and F.R. Robinson, Jr., *"Dynamic Loads on a Shipboard Crane Boom Due to Ship Motion,"* Naval Construction Battalion Center, in: Offshore Technology Conference Proceedings, OTC Paper 783,321 (May 1978).

Motion of the ship produces dynamic loads in a ship-mounted crane boom. Nonlinear equations for determining these loads are developed using vector analysis and rotating coordinate frames. Once computed, the load functions are incorporated into the flexible boom matrix equation of motion. The elastic response of the boom to these time varying inertial loads can then be computed.

305. Ward, Thomas M., *"Amphibious Vehicle Cargo Transfer Facility,"* Patent Disclosure, Naval Civil Engineering Laboratory (Feb 1988).

The Amphibious Vehicle Cargo Transfer Facility (AVCTF) is illustrated in the attached figure where it is shown serving as a LCAC staging platform. The AVCTF is composed of a submerged pontoon assembly supporting a landing deck and pillar crane. The pontoon provides flotation and the pumping machinery necessary to ballast and trim the assembly so that the landing deck may be lowered to receive a craft and then raised to lift the craft above the action of the waves. The pillar crane is used to transfer cargo. In the elevated position, the structure is free of wave action and the craft and the crane are mechanically joined so that cargo motion relative to the craft is at a minimum. The pontoon is positioned far enough below the water surface so that it will occupy a region of reduced wave action. As these struts have a small waterplane area, they can only produce small disturbing forces. Thus, the motion of the AVCTF due to wave action is reduced to a minimum.

306. Warman, C.P., *"Mechanism for Transferring Loads Through Tensioned, Controlled Cables,"* US PATENT-3 500 764 (Mar 1970).

This invention relates to improvements in ship to ship, or ship to shore cargo transfer systems and more particularly to a cargo transfer system which maintains constant tension on the support lines there between and a constant tension on a winch line which moves the cargo from ship to ship, or from ship to shore.

A system for maintaining a lineal element, such as load transfer cables, at a constant tension to enable the transfer of a load, such as parcels, cargo, or the like, from one station to another, even though one or both stations are relatively movable. Provision is made to maintain constant tension on winch lines, to enable the transfer of loads between two fixed stations, between a ship at sea

and a stationary loading dock, or between two ships at sea, which are relatively movable, by utilizing a continuously rotating, slipping clutch, which clutch is continuously cooled by circulating a fluid media therethrough to maintain the friction elements therein at a temperature below which the friction elements would become damaged.

307. Weiner, T., *"Apparatus For Loading And Unloading Floating Vessels,"* US PATENT-2 946 466 (Jul 1960).

This invention relates to apparatus for loading and unloading articles from a floating vessel, and in particular relates to apparatus wherein movement of means for supporting articles to be loaded or unloaded is synchronized with movement of the vessel.

It is an object of this invention to provide an apparatus for loading and unloading a floating vessel which eliminates the danger above set forth. More specifically, it is an object of this invention to provide a combination of means for supporting articles to be loaded and unloaded from a floating vessel, for moving the supporting means between a vessel loading and unloading position and a remote loading and unloading position and for synchronizing the movement of the supporting means with the movement of the vessel, when the supporting means is in the vessel loading and unloading position, such that there exists no possibility of damage to the articles being loaded and unloaded or to the vessel from which the articles are being loaded or unloaded.

308. Welch, R.E. and A. Lo, *"CWA Project 4006, Summary Report Dynamic Analysis and Testing of Barge Mounted Construction Cranes,"* CEL (Jul 1979).

309. Welch, R.E. and F.J. Vyzral, *"Development of Ratings and Dynamic Simulation Procedures for Shipboard Mobile Cranes,"* IIT Research Institute Report J6381 (Sep 1976).

This report presents the results of the first phase of a research project which is related to the development of rating and dynamic structural analysis procedures for mobile construction cranes used in container offloading operations from cargo vessels. Objectives of the project are to develop, for shipboard mobile cranes: (1) simplified crane rating procedures which determine acceptable operating criteria and capacities both in general and for selected specific cranes; and (2) an analytical simulation of crane operations incorporating ship motions, crane dynamics and the effect of motion compensating systems on crane motions and forces based on a dynamic structural analysis procedure of the crane.

The invention has as one of its principal objects the provision of a gangplank that automatically adjusts itself to changes in the tides and various other conditions that affect the level of a floating vessel.

310. Welch R.E., F.J. Vyzral, and E. Hahn, *"Development of Ratings and Dynamic Simulation Procedures for Shipboard Mobile Cranes, Second Interim Technical Report,"* Synamic Simulation Procedures, IIT Research Institute Report J6381 (Nov 1976).

311. Wilkins, D. and D. Bagnell, *"HISEACOTS (High Seastate Container Transfer System) Design Loads Criteria and Analysis for the Cargo Interface,"* Band Lavis And Associates, Inc. BLA-WP-220A-1 (May 1988).

This report summarizes the design loads criteria and analysis for the cargo interface with the U.S. Army's High Seastate Container Transfer System (HISEACOTS). The report comprises one of a series of task reports documenting the design development of the prototype HISEACOTS.

312. Wilson, Jeffrey V. and William D. Briggs, *"Linked-Spar Motion-Compensated Lifted System,"* US PATENT-4 280 430 (Jul 1981).

A system for operating a lifting cable over the side of a ship at sea in which a spar buoy having an adjustable lifting capacity is coupled to the ship by a rigid linkage which is free to pivot on an axis attached to the deck. The lifting cable is suspended from a first sheave which is mounted above a central, longitudinal channel in the spar buoy. The linkage is attached to the top of the spar buoy such that the spar buoy may rotate about an axis normal to the deck axis of the linkage and pivot on an axis normal to the longitudinal axis of the spar buoy. A second sheave is mounted on the deck axis so that the distance between the sheaves does not change as the linkage rotates on its axis. The lifting cable is fed from a winch on the ship over the sheaves and falls through the longitudinal channel. The invention operates to decouple the motion of the ship from the lifting cable so that the vertical motion of the cable is controlled by the motion of the spar buoy. A topping lift technique for deck-handling the system and an emergency disconnect feature are also disclosed.

313. Witz, J.A. and M.H. Patel, *"Control of Marine Vehicles with Pneumatic Compliances,"* Engineering Structures, Vol. 9, No. 2, pp. 124-133 (Apr 1987).

This paper is concerned with the use of pneumatic compliances to control the heave, roll and pitch motions of marine vehicles when disturbed by operational loads. The pneumatic compliances are in the form of open bottom air tanks attached to the vessel at the water line and extending above and below still water level. Each tank traps a volume of air above its internal water level. Active operation of these tanks involved controlling the amount of air trapped within the tanks. Three application studies are presented which involve suppression of motion due to vessel loading and crane operation on semi-submersible and monohull vessels.

314. Wolfe, M.J. and S.K. Wang, *"Impact and Operational Tests of the Container Hopper,"* NCEL Report N-1313 (Nov 1973).

The container hopper is designed to attenuate the swinging motions of a maritime van container suspended from a floating crane and then guide the container directly onto a truck trailer. It was developed under the auspices of the Marine Corps Development and Education Command and the Naval Facilities Engineering Command. There were two major phases in the development of the hopper. The first consisted of impact tests on one of the hopper shock absorbers. The second phase was a fully operational evaluation of the hopper during OSDOC II (Offshore Discharge Of Containership II) exercise in which a containership anchored 1 mile off the Virginia coast was unloaded with a floating crane. The crane lowered containers through the hopper onto flatbed semi-trailers, MILVAN chassis, and tandem rigs. Like the crane, the hopper and trucks were on a floating platform. Loading times as short as 1 minute were achieved.

315. Wolfson, Lt. Marc W., *"VLCC Lightering Operations in Southern California,"* US Coast Guard Marine Safety Office, Presented at Proceedings Oil Spill Conference (Mar 1979).

The large number of oil refineries in Southern California, lack of deepwater port facilities for very large crude carriers, and the large amount of crude oil now available from the Alaska pipeline have necessitated the development of a full-time lightering operation in the lee of San Clemente Island. The three companies presently involved- Shell, Chevron, and Coastal States Gas Corporation- have submitted operation manuals for lightering and contingency plans for handling emergency situations and oil spills. The Southern California Pollution Contingency Organization, an oil cleanup cooperative based in Long Beach, has been contracted by the lightering companies to respond on the event of an oil spill. Each lightering operation consists of a number of phases and requires expert lightering masters and an experienced crew. Since the first lightering on July 22, 1976, Coast Guard boarding teams from both the Los Angeles Captain of the Port Office and the San Diego Marine Safety Office have boarded and monitored more than 70 lighterings. The safety record has been impressive: there have been no major spills and relatively few deficiencies uncovered during tanker operations.

316. Wudtke, Donald J., "*Motion Compensator And Control System For Crane,*" US PATENT-4 354 608 (Oct 1982).

A motion compensation system for a crane hoist serves to assist the crane operator in safely lifting loads from the deck of a heaving work boat. The crane hook follows the motion of the load because a level of pre-tension is maintained on the line by use of a counterweight connected to the reeving system. A hydraulic cylinder connected to the counterweight provides for locking movement of the counterweight and also provides a cushion at both ends of its travel. Movement of the piston in the cylinder is controlled by a system including a check valve controlling flow between opposite ends of the cylinder which permits the reeving system to take up line. A limit switch responds to movement of the piston and counterweight near the top of their travel to actuate a light to warn the operator of a need to pay out line. As the piston and counterweight approach the bottom of their travel which indicates the load is moving upward, another limit switch activates a light to indicate time to lift the load. A relief valve in parallel with the operator-controlled switch responds to excessive load to permit more line to be paid out. A separate pressure-responsive switch responds to normal working pressure in the rod end of the cylinder to prevent line from being paid out even though the operator might inadvertently provide an input to the operator-controlled switch.

317. Yumori, I. Roy, "*Impact of Ship Motion on At-Sea Cargo Transfer: Survey of At-Sea Cargo Transfer Analysis, Design, and Operation,*" NOSC TR 1020 (Mar 1985).

U.S. Navy, university, and private industry groups that have had experience in the analysis, design, or operation of at-sea cargo transfer equipment were contacted. A literature search was used to identify 48 related publications. A simple analysis was made to compare empirical design rules to analytical values. An examination of underway replenishment (UNREP) records was performed to evaluate the ability of current UNREP equipment to perform heavy-weather transfers.

The following are results from this study: (1) Past analysis of relative motions for over-the-side transfer did not include breakwater effect of the supply ship on the receiving lighter. This effect protects the lighter on the downwave side but increases motions on the upwave side. (2) Heavy-lift UNREP cannot be performed in high sea states, under existing guidelines. (3) Existing empirical design rules for UNREP equipment are conservative and should be re-evaluated. (4) An experienced operator can make up for unsophisticated equipment. (5) Existing UNREP is

being used in sea states 4 to 6, but transfer rates of material are seriously degraded. (6) The bottleneck in the transfer of material does not lie in the UNREP equipment, but in the ability to clear the receiving area, especially with small ships. (7) Roll stabilization of the small combatant ships can improve transfer rates.

318. Zarnick, E., C. Turner, and J. Hoyt, *"Model Experiments of RO/RO Ships Off-Loading Performance in Waves and Current,"* DTNSRDC/SPD-1046-01 (Dec 1982).

Experiments were conducted in waves and calm water to evaluate the performance of several platforms made up of pontoon barges for offloading RO/RO ships in support of Assault Operations where port facilities era not available. A ferry/causeway consisting of three barges in line was attached to each platform. The experiments were conducted in sea and swell with and without current and measurements obtained of the platform motions and the mooring forces. The mooring forces or drag of the platform in current without waves was also measured. The results of the experiments in waves and calm water are presented in graphs and tables in the report. The platform configuration designed for the SS GREAT LAND Class appeared to be superior to the other platforms examined. However, relative motion between the barges and the mooring forces were large, significant values of 10 degrees and 150 KIPS, respectively (single amplitude), when waves and current were coming abeam to the platform/causeway system.

319. Zwibel, H.S. and D.A. Davis, *"Cargo Transfer at Sea - The Pendulation of Loads Suspended From Shipboard Cranes,"* NCEL Report TN N-1257 (Dec 1972).

A theory has been developed which could aid Navy materials handling specialists in their effort to evaluate load transfer systems for a modular port facility. The theory predicts the horizontal response of an unrestrained, wire suspended load in regular and random seas. The line length is allowed to vary with time, hence the resulting load response in random seas is characterized as a non-stationary random process.

The analysis is used to predict the motion of a load freely suspended from the boom of a Navy 100-ton floating crane. The results from the analysis and from the full scale tests at sea confirm in even moderate sea states. Taglines or other means of restraint will be required from inception through completion of each load transfer.

320. Zwibel, H.S., *"Motion of Freely Suspended Loads Due to Horizontal Ship Motion in Random Head Seas (N-1187),"* NCEL Report N-1187 (Oct 1971).

The theory is developed for the swinging motion induced in a wire suspended load due to the horizontal motion of a ship. An explicit formula is obtained for the significant amplitude of horizontal load motion when the ship is exposed to random head seas. Numerical results are presented for two typical cargo ships in a sea state three. It is found that very large motions are suffered by the load. For critical line lengths, resonance effects magnify the ship motion by several orders of magnitude. These results will be used to assist in the development of on-loading and off-loading devices for cargo vessels in open beach operations.

321. Zwibel, H.S. and D.A. Davis, *"A Treatment of a Non-Stationary Random Process - Load Transfer at Sea,"* NCEL (Oct 1972).

Many of the problems in shock and vibration are random in nature. The majority, representable as stationary stochastic processes, are analyzable by a variety of analytical techniques. There are, however, situations for which the process is non-stationary, e.g., transient phenomena, time variation of control parameters, etc. For these non-stationary processes, most of the analytic tools used for stationary processes are not applicable. In this paper, we treat a system that is non-stationary because of time varying parameters.

This non-stationary problem arises during off-shore cargo handling operations. A load is raised, shifted, and then lowered by a crane mounted on a floating platform. Horizontal boom motion (caused by wave-induced platform motion) forces the load line system to oscillate. Due to the raising and lowering of the load, the physical properties of this pendulum change with time. The magnitude of this induced oscillation for both random sea condition and swell is of interest. For swell, the system is not random; however, for a wind developed sea the system is stochastic due to the randomness of the forcing function. Both situations are discussed in this paper.